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(54) Title: IMMUNOCONJUGATES FOR THE TREATMENT OF TUMOURS

(57) Abstract: A pharmaceutical composition comprising a conjugate of a cytokine and a tumor targeting moiety (TTM) and a pharmaceutically acceptable excipient, wherein the cytokine is present in an amount which does not induce a negative feedback mechanism.

WO 2003/093478 A1

IMMUNOCONJUGATES FOR THE TREATMENT OF TUMOURS

Field of the Invention

- 5 The present invention relates to a pharmaceutical composition and uses thereof.

Background of the Invention

10 The antitumor activity of some cytokines is well known and described. Some cytokines have already been used therapeutically in humans. For example, cytokines such as IL-2 and IFN- γ have shown positive antitumoral activity in patients with different types of tumors, such as kidney metastatic carcinoma, hairy cell leukemia, Kaposi sarcoma, melanoma, multiple myeloma, and the like. Other cytokines like IFN β , the Tumor Necrosis Factor (TNF) α , TNF β , IL-1, 4, 6, 12, 15 and the Colony
15 Stimulating Factors (CSFs) have shown a certain antitumoral activity on some types of tumors.

In general, the therapeutic use of cytokines is strongly limited by their systemic toxicity. TNF, for example, was originally discovered for its capacity for inducing the
20 hemorrhagic necrosis of some tumors, and for its *in vitro* cytotoxic effect on different tumoral lines, but is subsequently proved to have strong pro-inflammatory activity, which can, in case of overproduction conditions, dangerously affect the human body.

As the systemic toxicity is a fundamental problem with the use of pharmacologically
25 active amounts of cytokines in humans, novel derivatives and therapeutic strategies are now under evaluation, aimed at reducing the toxic effects of this class of biological effectors while keeping their therapeutic efficacy.

Some novel approaches are directed to:

- 30 a) the development of fusion proteins which can deliver TNF into the tumor and increase the local concentration. For example, the fusion proteins consisting of TNF and tumor specific-antibodies have been produced;

ConjugateField of the Invention

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25 active amounts of cytokines in humans, novel derivatives and therapeutic strategies are now under evaluation, aimed at reducing the toxic effects of this class of biological effectors while keeping their therapeutic efficacy.

Some novel approaches are directed to:

- 30 a) the development of fusion proteins which can deliver TNF into the tumor and increase the local concentration. For example, the fusion proteins consisting of TNF and tumor specific-antibodies have been produced;

- b) the development of TNF mutants which maintain the antitumoral activity and have a reduced systemic toxicity. Accordingly, mutants capable of selectively recognizing only one receptor have already been prepared;
 - c) the use of anti-TNF antibodies able to reduce some toxic effects of TNF without compromising its antitumoral activity. Such antibodies have already been described in literature;
 - d) the use of TNF derivatives with a higher half-life (for example TNF conjugated with polyethylene glycol).
- 10 The preparation of TNF derivatives capable of selectively targeting the tumoral sites has recently been reported. For example, a fusion protein has been described, obtained by fusing the gene of the heavy chain of an anti-transferrin receptor mAb and the TNF gene, or a fusion protein of TNF with the "hinge" region of a monoclonal antibody against the tumor-associated TAG72 antigen, or a Fv-TNF
- 15 fusion protein.

EP 251 494 discloses a system for administering a diagnostic or therapeutic agent, which comprises: an antibody conjugated with avidin or streptavidin, an agent capable of complexing the conjugated antibody and a compound consisting of the diagnostic or therapeutic agent conjugated with biotin, which are administered sequentially and adequately delayed, so as to allow the localization of the therapeutic or diagnostic agent through the biotin-streptavidin interaction on the target cell recognized by the antibody. The described therapeutic or diagnostic agents comprise metal chelates, in particular chelates of radionuclides and low molecular weight antitumoral agents such as cis-platinum, doxorubicin, etc.

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EP 496 074 discloses a method which provides the sequential administration of a biotinylated antibody, avidin or streptavidin and a biotinylated diagnostic or therapeutic agent. Although cytotoxic agents like ricin are generically mentioned, the application relative to radiolabelled compounds is mostly disclosed.

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WO 95/15979 discloses a method for localizing highly toxic agents on cellular targets, based on the administration of a first conjugate comprising the specific target molecule conjugated with a ligand or an anti-ligand followed by the administration of

a second conjugate consisting of the toxic agent bound to an anti-ligand or to the ligand.

WO 99/13329 discloses a method for targeting a molecule to tumoral angiogenic vessels, based on the conjugation of said molecule with ligands of NGR receptors. A number of molecules have been suggested as possible candidates, but doxorubicin only is specifically described. No use of ligands of NGR receptors as cytokines vehicles to induce immuno responses is disclosed.

In WO01/61017 the current inventor describes how surprisingly he has found that the therapeutic index of certain cytokines can be remarkably improved and their immunotherapeutic properties can be enhanced by coupling with a ligand of the aminopeptidase-N receptor (CD13). CD13 is a transmembrane glycoprotein of 150kDa which is highly conserved in various species. It is expressed on normal cells as well as in myeloid tumor lines, in the angiogenic endothelium and in some epithelia. The CD13 receptor is usually identified as the "NGR" receptor, in that its peptide ligands share the amino acid "NGR" motif.

However, there remains a need for further and improved pharmaceutical compositions and methods for the treatment and diagnosis of cancer.

Summary of the Invention

Drug delivery and penetration into neoplastic cells is critical for the effectiveness of tumor chemotherapy. We have now found that surprisingly targeted delivery of picogram doses of cytokines enhances the penetration of chemotherapeutic drugs. In more detail, we have found that delivery of very low doses of cytokines to tumors and the tumor-associated environment including tumor vasculature represents a new approach to avoiding negative feedback mechanisms and to preserve its ability to alter drug-penetration barriers. The present invention thus represents a novel and surprising strategy for increasing the therapeutic index of chemotherapeutic drugs. In a preferred embodiment, we have found using vascular targeting achieved by coupling TNF with CNGRC, a peptide that targets the tumor neovasculature, that this treatment enhanced 8-10 times the therapeutic efficacy of doxorubicin, with no evidence of

increased toxicity. Similarly, vascular targeting enhanced the efficacy of melphalan, a different chemotherapeutic drug. Synergy with chemotherapy was observed with 3-5 ng/kg of targeted TNF (i.p.), 10^6 -fold lower than the LD_{50} and 10^5 -fold lower than the dose required for non-targeted TNF. In addition, we have also found that targeted delivery of low doses of TNF to tumor vessels does not induce the release of soluble TNF receptors in circulation. We have also found that RGD-TNF and IFN γ -NGR are active in the picogram range. We have also shown that NGR-TNF increases the effect of cisplatin. These results indicate that the delivery of minute amounts of cytokines to tumor vessels represents a new approach to avoid negative feedback mechanisms and to preserve its ability to alter drug-penetration barriers. Vascular targeting in this way represents a novel strategy for increasing the therapeutic index of chemotherapeutic drugs.

Statements of the Invention

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According to one aspect of the present invention there is provided a pharmaceutical composition comprising a conjugate of a cytokine and a tumor targeting moiety (TTM) and a pharmaceutically acceptable carrier, diluent or excipient, wherein the cytokine is present in an amount which does not induce a negative feedback mechanism. Thus, the cytokine is present in an amount which does not induce soluble cytokine receptor shedding.

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Preferably the conjugate is present in an amount to provide a dosage in the range of 0.5 to 500 ng/kg, more preferably 1 to 50 ng/kg, and most preferably 5 to 15 ng/kg.

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In one embodiment the cytokine is an inflammatory cytokine.

In another embodiment the cytokine is a chemotherapeutic cytokine.

30 Preferably the cytokine is selected from: TNF, such as TNF α , TNF β , IFN α , IFN β , IFN γ , IL-1, 2, 4, 6, 12, 15, EMAP II, vascular endothelial growth factor (VEGF), PDGF, PD-ECGF or a chemokine.

In a more preferred embodiment the cytokine is TNF- α , TNF- β or IFN- γ , most preferably TNF- α or TNF- β .

In one embodiment the TTM is a binding partner such as a ligand of, or antibody to a
5 tumor cell surface molecule such as a receptor, marker or other extracellular component.

In another embodiment the TTM is a tumor vasculature targeting moiety (TVTM), and may be a binding partner such as a ligand of, or antibody to a tumor vasculature
10 cell surface molecule such as a receptor, marker or other extracellular component.

In one embodiment the TTM is an antibody or fragment thereof.

In another embodiment the TTM is a ligand or fragment thereof.
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In a preferred embodiment the TTM is a peptide containing the NGR or RGD motif, or is HIV-tat, Annexin V, Osteopontin, Fibronectin, Collagen Type I or IV, Hyaluronate or Ephrin, or is a binding partner, such as an antibody to oncofetal fibronectin; or is a fragment of any of the foregoing. In a more preferred embodiment
20 the TTM contains the NGR motif. In a most preferred embodiment the TTM is CNGRCVSGCAGRC, NGRAHA, GNGRG, cycloCVLNGRMEC, linear or cyclic CNGRC.

In another preferred embodiment the TTM is a peptide containing the RGD motif.
25

In one embodiment the TTM is targeted to VEGFR, ICAM 1, 2 or 3, PECAM-1, CD13, VCAM-1, Selectin, ActRII, ActRIIB, ActRI, ActRIB, CD44, aminopeptidase A, aminopeptidase N (CD13), $\alpha v \beta 3$ integrin, $\alpha v \beta 5$ integrin, FGF-1, 2, 3, or 4, IL-1R, EPHR, MMP, NG2, tenascin, oncofetal fibronectin, PD-ECGFR, TNFR, PDGFR or
30 PSMA.

Combinations of preferred targeting moieties and cytokines which may be used in the present invention are shown in the Table below.

Cytokine	Targeting Moiety
TNF- α	RGD-CONTAINING PEPTIDE
TNF- β	RGD-CONTAINING PEPTIDE
IFN- α	RGD-CONTAINING PEPTIDE
IFN- β	RGD-CONTAINING PEPTIDE
IFN- γ	RGD-CONTAINING PEPTIDE
IL-2	RGD-CONTAINING PEPTIDE
IL-12	RGD-CONTAINING PEPTIDE
EMAP II	RGD-CONTAINING PEPTIDE
VEGF	RGD-CONTAINING PEPTIDE
IL-1	RGD-CONTAINING PEPTIDE
IL-6	RGD-CONTAINING PEPTIDE
IL-12	RGD-CONTAINING PEPTIDE
PDGF	RGD-CONTAINING PEPTIDE
PD-ECGF	RGD-CONTAINING PEPTIDE
CXC chemokine	RGD-CONTAINING PEPTIDE
CC chemokine	RGD-CONTAINING PEPTIDE
C chemokine	RGD-CONTAINING PEPTIDE
IL-15	RGD-CONTAINING PEPTIDE
TNF- α	NGR-CONTAINING PEPTIDE
TNF- β	NGR-CONTAINING PEPTIDE
IFN- α	NGR-CONTAINING PEPTIDE
IFN- β	NGR-CONTAINING PEPTIDE
IFN- γ	NGR-CONTAINING PEPTIDE
IL-2	NGR-CONTAINING PEPTIDE
IL-12	NGR-CONTAINING PEPTIDE
EMAP II	NGR-CONTAINING PEPTIDE
VEGF	NGR-CONTAINING PEPTIDE
IL-1	NGR-CONTAINING PEPTIDE
IL-6	NGR-CONTAINING PEPTIDE
IL-12	NGR-CONTAINING PEPTIDE
PDGF	NGR-CONTAINING PEPTIDE
PD-ECGF	NGR-CONTAINING PEPTIDE
CXC chemokine	NGR-CONTAINING PEPTIDE
CC chemokine	NGR-CONTAINING PEPTIDE
C chemokine	NGR-CONTAINING PEPTIDE
IL-15	NGR-CONTAINING PEPTIDE
TNF- α	Ligand to VEGFR
TNF- β	Ligand to VEGFR
IFN- α	Ligand to VEGFR
IFN- β	Ligand to VEGFR
IFN- γ	Ligand to VEGFR
IL-2	Ligand to VEGFR
IL-12	Ligand to VEGFR
EMAP II	Ligand to VEGFR

VEGF	Ligand to VEGFR
IL-1	Ligand to VEGFR
IL-6	Ligand to VEGFR
IL-12	Ligand to VEGFR
PDGF	Ligand to VEGFR
PD-ECGF	Ligand to VEGFR
CXC chemokine	Ligand to VEGFR
CC chemokine	Ligand to VEGFR
C chemokine	Ligand to VEGFR
IL-15	Ligand to VEGFR
TNF- α	Ab to VEGFR
TNF- β	Ab to VEGFR
IFN- α	Ab to VEGFR
IFN- β	Ab to VEGFR
IFN- γ	Ab to VEGFR
IL-2	Ab to VEGFR
IL-12	Ab to VEGFR
EMAP II	Ab to VEGFR
VEGF	Ab to VEGFR
IL-1	Ab to VEGFR
IL-6	Ab to VEGFR
IL-12	Ab to VEGFR
PDGF	Ab to VEGFR
PD-ECGF	Ab to VEGFR
CXC chemokine	Ab to VEGFR
CC chemokine	Ab to VEGFR
C chemokine	Ab to VEGFR
IL-15	Ab to VEGFR
TNF- α	HIV-tat
TNF- β	HIV-tat
IFN- α	HIV-tat
IFN- β	HIV-tat
IFN- γ	HIV-tat
IL-2	HIV-tat
IL-12	HIV-tat
EMAP II	HIV-tat
VEGF	HIV-tat
IL-1	HIV-tat
IL-6	HIV-tat
IL-12	HIV-tat
PDGF	HIV-tat
PD-ECGF	HIV-tat
CXC chemokine	HIV-tat

CC chemokine	HIV-tat
C chemokine	HIV-tat
IL-15	HIV-tat
TNF- α	Ligand to ICAM 1,2 or 3
TNF- β	Ligand to ICAM 1,2 or 3
IFN- α	Ligand to ICAM 1,2 or 3
IFN- β	Ligand to ICAM 1,2 or 3
IFN- γ	Ligand to ICAM 1,2 or 3
IL-2	Ligand to ICAM 1,2 or 3
IL-12	Ligand to ICAM 1,2 or 3
EMAP II	Ligand to ICAM 1,2 or 3
VEGF	Ligand to ICAM 1,2 or 3
IL-1	Ligand to ICAM 1,2 or 3
IL-6	Ligand to ICAM 1,2 or 3
IL-12	Ligand to ICAM 1,2 or 3
PDGF	Ligand to ICAM 1,2 or 3
PD-ECGF	Ligand to ICAM 1,2 or 3
CXC chemokine	Ligand to ICAM 1,2 or 3
CC chemokine	Ligand to ICAM 1,2 or 3
C chemokine	Ligand to ICAM 1,2 or 3
IL-15	Ligand to ICAM 1,2 or 3
TNF- α	Ab to ICAM 1,2 or 3
TNF- β	Ab to ICAM 1,2 or 3
IFN- α	Ab to ICAM 1,2 or 3
IFN- β	Ab to ICAM 1,2 or 3
IFN- γ	Ab to ICAM 1,2 or 3
IL-2	Ab to ICAM 1,2 or 3
IL-12	Ab to ICAM 1,2 or 3
EMAP II	Ab to ICAM 1,2 or 3
VEGF	Ab to ICAM 1,2 or 3
IL-1	Ab to ICAM 1,2 or 3
IL-6	Ab to ICAM 1,2 or 3
IL-12	Ab to ICAM 1,2 or 3
PDGF	Ab to ICAM 1,2 or 3
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CXC chemokine	Ab to ICAM 1,2 or 3
CC chemokine	Ab to ICAM 1,2 or 3
C chemokine	Ab to ICAM 1,2 or 3
IL-15	Ab to ICAM 1,2 or 3
TNF- α	Ligand to PECAM-1/CD31
TNF- β	Ligand to PECAM-1/CD31
IFN- α	Ligand to PECAM-1/CD31
IFN- β	Ligand to PECAM-1/CD31

IFN- γ	Ligand to PECAM-1/CD31
IL-2	Ligand to PECAM-1/CD31
IL-12	Ligand to PECAM-1/CD31
EMAP II	Ligand to PECAM-1/CD31
VEGF	Ligand to PECAM-1/CD31
IL-1	Ligand to PECAM-1/CD31
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TNF- β	Ab to PECAM-1/CD31
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IFN- β	Ab to PECAM-1/CD31
IFN- γ	Ab to PECAM-1/CD31
IL-2	Ab to PECAM-1/CD31
IL-12	Ab to PECAM-1/CD31
EMAP II	Ab to PECAM-1/CD31
VEGF	Ab to PECAM-1/CD31
IL-1	Ab to PECAM-1/CD31
IL-6	Ab to PECAM-1/CD31
IL-12	Ab to PECAM-1/CD31
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C chemokine	Ab to PECAM-1/CD31
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IFN- β	Ligand to VCAM-1
IFN- γ	Ligand to VCAM-1
IL-2	Ligand to VCAM-1
IL-12	Ligand to VCAM-1
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TNF- β	Ab to VCAM-1
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IFN- β	Ab to VCAM-1
IFN- γ	Ab to VCAM-1
IL-2	Ab to VCAM-1
IL-12	Ab to VCAM-1
EMAP II	Ab to VCAM-1
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IL-1	Ab to VCAM-1
IL-6	Ab to VCAM-1
IL-12	Ab to VCAM-1
PDGF	Ab to VCAM-1
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CC chemokine	Ab to VCAM-1
C chemokine	Ab to VCAM-1
IL-15	Ab to VCAM-1
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TNF- β	Ligand to Selectin
IFN- α	Ligand to Selectin
IFN- β	Ligand to Selectin
IFN- γ	Ligand to Selectin
IL-2	Ligand to Selectin
IL-12	Ligand to Selectin
EMAP II	Ligand to Selectin
VEGF	Ligand to Selectin
IL-1	Ligand to Selectin
IL-6	Ligand to Selectin
IL-12	Ligand to Selectin
PDGF	Ligand to Selectin
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IL-12	Ab to Selectin
EMAP II	Ab to Selectin
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IL-6	Ab to Selectin
IL-12	Ab to Selectin
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IFN- β	Ligand to ActRII, ActRIIB, ActRI or ActRIB
IFN- γ	Ligand to ActRII, ActRIIB, ActRI or ActRIB
IL-2	Ligand to ActRII, ActRIIB, ActRI or ActRIB
IL-12	Ligand to ActRII, ActRIIB, ActRI or ActRIB
EMAP II	Ligand to ActRII, ActRIIB, ActRI or ActRIB
VEGF	Ligand to ActRII, ActRIIB, ActRI or ActRIB
IL-1	Ligand to ActRII, ActRIIB, ActRI or ActRIB
IL-6	Ligand to ActRII, ActRIIB, ActRI or ActRIB
IL-12	Ligand to ActRII, ActRIIB, ActRI or ActRIB
PDGF	Ligand to ActRII, ActRIIB, ActRI or ActRIB
PD-ECGF	Ligand to ActRII, ActRIIB, ActRI or ActRIB

CXC chemokine	Ligand to ActRII, ActRIIB, ActRI or ActRIB
CC chemokine	Ligand to ActRII, ActRIIB, ActRI or ActRIB
C chemokine	Ligand to ActRII, ActRIIB, ActRI or ActRIB
IL-15	Ligand to ActRII, ActRIIB, ActRI or ActRIB
TNF- α	Ab to ActRII, ActRIIB, ActRI or ActRIB
TNF- β	Ab to ActRII, ActRIIB, ActRI or ActRIB
IFN- α	Ab to ActRII, ActRIIB, ActRI or ActRIB
IFN- β	Ab to ActRII, ActRIIB, ActRI or ActRIB
IFN- γ	Ab to ActRII, ActRIIB, ActRI or ActRIB
IL-2	Ab to ActRII, ActRIIB, ActRI or ActRIB
IL-12	Ab to ActRII, ActRIIB, ActRI or ActRIB
EMAP II	Ab to ActRII, ActRIIB, ActRI or ActRIB
VEGF	Ab to ActRII, ActRIIB, ActRI or ActRIB
IL-1	Ab to ActRII, ActRIIB, ActRI or ActRIB
IL-6	Ab to ActRII, ActRIIB, ActRI or ActRIB
IL-12	Ab to ActRII, ActRIIB, ActRI or ActRIB
PDGF	Ab to ActRII, ActRIIB, ActRI or ActRIB
PD-ECGF	Ab to ActRII, ActRIIB, ActRI or ActRIB
CXC chemokine	Ab to ActRII, ActRIIB, ActRI or ActRIB
CC chemokine	Ab to ActRII, ActRIIB, ActRI or ActRIB
C chemokine	Ab to ActRII, ActRIIB, ActRI or ActRIB
IL-15	Ab to ActRII, ActRIIB, ActRI or ActRIB
TNF- α	Annexin V
TNF- β	Annexin V
IFN- α	Annexin V
IFN- β	Annexin V
IFN- γ	Annexin V
IL-2	Annexin V
IL-12	Annexin V
EMAP II	Annexin V
VEGF	Annexin V
IL-1	Annexin V
IL-6	Annexin V
IL-12	Annexin V
PDGF	Annexin V
PD-ECGF	Annexin V
CXC chemokine	Annexin V
CC chemokine	Annexin V
C chemokine	Annexin V
IL-15	Annexin V

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TNF- β	Ligand to CD44
IFN- α	Ligand to CD44
IFN- β	Ligand to CD44
IFN- γ	Ligand to CD44
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IL-12	Ligand to CD44
EMAP II	Ligand to CD44
VEGF	Ligand to CD44
IL-1	Ligand to CD44
IL-6	Ligand to CD44
IL-12	Ligand to CD44
PDGF	Ligand to CD44
PD-ECGF	Ligand to CD44
CXC chemokine	Ligand to CD44
CC chemokine	Ligand to CD44
C chemokine	Ligand to CD44
IL-15	Ligand to CD44
TNF- α	Ab to CD44
TNF- β	Ab to CD44
IFN- α	Ab to CD44
IFN- β	Ab to CD44
IFN- γ	Ab to CD44
IL-2	Ab to CD44
IL-12	Ab to CD44
EMAP II	Ab to CD44
VEGF	Ab to CD44
IL-1	Ab to CD44
IL-6	Ab to CD44
IL-12	Ab to CD44
PDGF	Ab to CD44
PD-ECGF	Ab to CD44
CXC chemokine	Ab to CD44
CC chemokine	Ab to CD44
C chemokine	Ab to CD44
IL-15	Ab to CD44
TNF- α	Osteopontin
TNF- β	Osteopontin
IFN- α	Osteopontin
IFN- β	Osteopontin
IFN- γ	Osteopontin
IL-2	Osteopontin
IL-12	Osteopontin

EMAP II	Osteopontin
VEGF	Osteopontin
IL-1	Osteopontin
IL-6	Osteopontin
IL-12	Osteopontin
PDGF	Osteopontin
PD-ECGF	Osteopontin
CXC chemokine	Osteopontin
CC chemokine	Osteopontin
C chemokine	Osteopontin
IL-15	Osteopontin
TNF- α	Fibronectin
TNF- β	Fibronectin
IFN- α	Fibronectin
IFN- β	Fibronectin
IFN- γ	Fibronectin
IL-2	Fibronectin
IL-12	Fibronectin
EMAP II	Fibronectin
VEGF	Fibronectin
IL-1	Fibronectin
IL-6	Fibronectin
IL-12	Fibronectin
PDGF	Fibronectin
PD-ECGF	Fibronectin
CXC chemokine	Fibronectin
CC chemokine	Fibronectin
C chemokine	Fibronectin
IL-15	Fibronectin
TNF- α	Collagen type I or IV
TNF- β	Collagen type I or IV
IFN- α	Collagen type I or IV
IFN- β	Collagen type I or IV
IFN- γ	Collagen type I or IV
IL-2	Collagen type I or IV
IL-12	Collagen type I or IV
EMAP II	Collagen type I or IV
VEGF	Collagen type I or IV
IL-1	Collagen type I or IV
IL-6	Collagen type I or IV
IL-12	Collagen type I or IV
PDGF	Collagen type I or IV
PD-ECGF	Collagen type I or IV

CXC chemokine	Collagen type I or IV
CC chemokine	Collagen type I or IV
C chemokine	Collagen type I or IV
IL-15	Collagen type I or IV
TNF- α	Hyaluronate
TNF- β	Hyaluronate
IFN- α	Hyaluronate
IFN- β	Hyaluronate
IFN- γ	Hyaluronate
IL-2	Hyaluronate
IL-12	Hyaluronate
EMAP II	Hyaluronate
VEGF	Hyaluronate
IL-1	Hyaluronate
IL-6	Hyaluronate
IL-12	Hyaluronate
PDGF	Hyaluronate
PD-ECGF	Hyaluronate
CXC chemokine	Hyaluronate
CC chemokine	Hyaluronate
C chemokine	Hyaluronate
IL-15	Hyaluronate
TNF- α	Ligand to FGF-1, 2, 3 or 4
TNF- β	Ligand to FGF-1, 2, 3 or 4
IFN- α	Ligand to FGF-1, 2, 3 or 4
IFN- β	Ligand to FGF-1, 2, 3 or 4
IFN- γ	Ligand to FGF-1, 2, 3 or 4
IL-2	Ligand to FGF-1, 2, 3 or 4
IL-12	Ligand to FGF-1, 2, 3 or 4
EMAP II	Ligand to FGF-1, 2, 3 or 4
VEGF	Ligand to FGF-1, 2, 3 or 4
IL-1	Ligand to FGF-1, 2, 3 or 4
IL-6	Ligand to FGF-1, 2, 3 or 4
IL-12	Ligand to FGF-1, 2, 3 or 4
PDGF	Ligand to FGF-1, 2, 3 or 4
PD-ECGF	Ligand to FGF-1, 2, 3 or 4
CXC chemokine	Ligand to FGF-1, 2, 3 or 4
CC chemokine	Ligand to FGF-1, 2, 3 or 4
C chemokine	Ligand to FGF-1, 2, 3 or 4
IL-15	Ligand to FGF-1, 2, 3 or 4
TNF- α	Ab to FGF-1, 2, 3 or 4
TNF- β	Ab to FGF-1, 2, 3 or 4
IFN- α	Ab to FGF-1, 2, 3 or 4

IFN- β	Ab to FGF-1, 2, 3 or 4
IFN- γ	Ab to FGF-1, 2, 3 or 4
IL-2	Ab to FGF-1, 2, 3 or 4
IL-12	Ab to FGF-1, 2, 3 or 4
EMAP II	Ab to FGF-1, 2, 3 or 4
VEGF	Ab to FGF-1, 2, 3 or 4
IL-1	Ab to FGF-1, 2, 3 or 4
IL-6	Ab to FGF-1, 2, 3 or 4
IL-12	Ab to FGF-1, 2, 3 or 4
PDGF	Ab to FGF-1, 2, 3 or 4
PD-ECGF	Ab to FGF-1, 2, 3 or 4
CXC chemokine	Ab to FGF-1, 2, 3 or 4
CC chemokine	Ab to FGF-1, 2, 3 or 4
C chemokine	Ab to FGF-1, 2, 3 or 4
IL-15	Ab to FGF-1, 2, 3 or 4
TNF- α	Ligand to IL-1R
TNF- β	Ligand to IL-1R
IFN- α	Ligand to IL-1R
IFN- β	Ligand to IL-1R
IFN- γ	Ligand to IL-1R
IL-2	Ligand to IL-1R
IL-12	Ligand to IL-1R
EMAP II	Ligand to IL-1R
VEGF	Ligand to IL-1R
IL-1	Ligand to IL-1R
IL-6	Ligand to IL-1R
IL-12	Ligand to IL-1R
PDGF	Ligand to IL-1R
PD-ECGF	Ligand to IL-1R
CXC chemokine	Ligand to IL-1R
CC chemokine	Ligand to IL-1R
C chemokine	Ligand to IL-1R
IL-15	Ligand to IL-1R
TNF- α	Ab to IL-1R
TNF- β	Ab to IL-1R
IFN- α	Ab to IL-1R
IFN- β	Ab to IL-1R
IFN- γ	Ab to IL-1R
IL-2	Ab to IL-1R
IL-12	Ab to IL-1R
EMAP II	Ab to IL-1R
VEGF	Ab to IL-1R
IL-1	Ab to IL-1R

IL-6	Ab to IL-1R
IL-12	Ab to IL-1R
PDGF	Ab to IL-1R
PD-ECGF	Ab to IL-1R
CXC chemokine	Ab to IL-1R
CC chemokine	Ab to IL-1R
C chemokine	Ab to IL-1R
IL-15	Ab to IL-1R
TNF- α	Ligand to CD31
TNF- β	Ligand to CD31
IFN- α	Ligand to CD31
IFN- β	Ligand to CD31
IFN- γ	Ligand to CD31
IL-2	Ligand to CD31
IL-12	Ligand to CD31
EMAP II	Ligand to CD31
VEGF	Ligand to CD31
IL-1	Ligand to CD31
IL-6	Ligand to CD31
IL-12	Ligand to CD31
PDGF	Ligand to CD31
PD-ECGF	Ligand to CD31
CXC chemokine	Ligand to CD31
CC chemokine	Ligand to CD31
C chemokine	Ligand to CD31
IL-15	Ligand to CD31
TNF- α	Ab to CD31
TNF- β	Ab to CD31
IFN- α	Ab to CD31
IFN- β	Ab to CD31
IFN- γ	Ab to CD31
IL-2	Ab to CD31
IL-12	Ab to CD31
EMAP II	Ab to CD31
VEGF	Ab to CD31
IL-1	Ab to CD31
IL-6	Ab to CD31
IL-12	Ab to CD31
PDGF	Ab to CD31
PD-ECGF	Ab to CD31
CXC chemokine	Ab to CD31
CC chemokine	Ab to CD31
C chemokine	Ab to CD31

IL-15	Ab to CD31
TNF- α	Ligand to EPHR
TNF- β	Ligand to EPHR
IFN- α	Ligand to EPHR
IFN- β	Ligand to EPHR
IFN- γ	Ligand to EPHR
IL-2	Ligand to EPHR
IL-12	Ligand to EPHR
EMAP II	Ligand to EPHR
VEGF	Ligand to EPHR
IL-1	Ligand to EPHR
IL-6	Ligand to EPHR
IL-12	Ligand to EPHR
PDGF	Ligand to EPHR
PD-ECGF	Ligand to EPHR
CXC chemokine	Ligand to EPHR
CC chemokine	Ligand to EPHR
C chemokine	Ligand to EPHR
IL-15	Ligand to EPHR
TNF- α	Ab to EPHR
TNF- β	Ab to EPHR
IFN- α	Ab to EPHR
IFN- β	Ab to EPHR
IFN- γ	Ab to EPHR
IL-2	Ab to EPHR
IL-12	Ab to EPHR
EMAP II	Ab to EPHR
VEGF	Ab to EPHR
IL-1	Ab to EPHR
IL-6	Ab to EPHR
IL-12	Ab to EPHR
PDGF	Ab to EPHR
PD-ECGF	Ab to EPHR
CXC chemokine	Ab to EPHR
CC chemokine	Ab to EPHR
C chemokine	Ab to EPHR
IL-15	Ab to EPHR
TNF- α	Ephrin
TNF- β	Ephrin
IFN- α	Ephrin
IFN- β	Ephrin
IFN- γ	Ephrin
IL-2	Ephrin

IL-12	Ephrin
EMAP II	Ephrin
VEGF	Ephrin
IL-1	Ephrin
IL-6	Ephrin
IL-12	Ephrin
PDGF	Ephrin
PD-ECGF	Ephrin
CXC chemokine	Ephrin
CC chemokine	Ephrin
C chemokine	Ephrin
IL-15	Ephrin
TNF- α	Ligand to MMP
TNF- β	Ligand to MMP
IFN- α	Ligand to MMP
IFN- β	Ligand to MMP
IFN- γ	Ligand to MMP
IL-2	Ligand to MMP
IL-12	Ligand to MMP
EMAP II	Ligand to MMP
VEGF	Ligand to MMP
IL-1	Ligand to MMP
IL-6	Ligand to MMP
IL-12	Ligand to MMP
PDGF	Ligand to MMP
PD-ECGF	Ligand to MMP
CXC chemokine	Ligand to MMP
CC chemokine	Ligand to MMP
C chemokine	Ligand to MMP
IL-15	Ligand to MMP
TNF- α	Ab to MMP
TNF- β	Ab to MMP
IFN- α	Ab to MMP
IFN- β	Ab to MMP
IFN- γ	Ab to MMP
IL-2	Ab to MMP
IL-12	Ab to MMP
EMAP II	Ab to MMP
VEGF	Ab to MMP
IL-1	Ab to MMP
IL-6	Ab to MMP
IL-12	Ab to MMP
PDGF	Ab to MMP

PD-ECGF	Ab to MMP
CXC chemokine	Ab to MMP
CC chemokine	Ab to MMP
C chemokine	Ab to MMP
IL-15	Ab to MMP
TNF- α	Ligand to NG2
TNF- β	Ligand to NG2
IFN- α	Ligand to NG2
IFN- β	Ligand to NG2
IFN- γ	Ligand to NG2
IL-2	Ligand to NG2
IL-12	Ligand to NG2
EMAP II	Ligand to NG2
VEGF	Ligand to NG2
IL-1	Ligand to NG2
IL-6	Ligand to NG2
IL-12	Ligand to NG2
PDGF	Ligand to NG2
PD-ECGF	Ligand to NG2
CXC chemokine	Ligand to NG2
CC chemokine	Ligand to NG2
C chemokine	Ligand to NG2
IL-15	Ligand to NG2
TNF- α	Ab to NG2
TNF- β	Ab to NG2
IFN- α	Ab to NG2
IFN- β	Ab to NG2
IFN- γ	Ab to NG2
IL-2	Ab to NG2
IL-12	Ab to NG2
EMAP II	Ab to NG2
VEGF	Ab to NG2
IL-1	Ab to NG2
IL-6	Ab to NG2
IL-12	Ab to NG2
PDGF	Ab to NG2
PD-ECGF	Ab to NG2
CXC chemokine	Ab to NG2
CC chemokine	Ab to NG2
C chemokine	Ab to NG2
IL-15	Ab to NG2
TNF- α	Ligand to tenascin
TNF- β	Ligand to tenascin

IFN- α	Ligand to tenascin
IFN- β	Ligand to tenascin
IFN- γ	Ligand to tenascin
IL-2	Ligand to tenascin
IL-12	Ligand to tenascin
EMAP II	Ligand to tenascin
VEGF	Ligand to tenascin
IL-1	Ligand to tenascin
IL-6	Ligand to tenascin
IL-12	Ligand to tenascin
PDGF	Ligand to tenascin
PD-ECGF	Ligand to tenascin
CXC chemokine	Ligand to tenascin
CC chemokine	Ligand to tenascin
C chemokine	Ligand to tenascin
IL-15	Ligand to tenascin
TNF- α	Ab to tenascin
TNF- β	Ab to tenascin
IFN- α	Ab to tenascin
IFN- β	Ab to tenascin
IFN- γ	Ab to tenascin
IL-2	Ab to tenascin
IL-12	Ab to tenascin
EMAP II	Ab to tenascin
VEGF	Ab to tenascin
IL-1	Ab to tenascin
IL-6	Ab to tenascin
IL-12	Ab to tenascin
PDGF	Ab to tenascin
PD-ECGF	Ab to tenascin
CXC chemokine	Ab to tenascin
CC chemokine	Ab to tenascin
C chemokine	Ab to tenascin
IL-15	Ab to tenascin
TNF- α	Ligand to PD-ECGFR
TNF- β	Ligand to PD-ECGFR
IFN- α	Ligand to PD-ECGFR
IFN- β	Ligand to PD-ECGFR
IFN- γ	Ligand to PD-ECGFR
IL-2	Ligand to PD-ECGFR
IL-12	Ligand to PD-ECGFR
EMAP II	Ligand to PD-ECGFR
VEGF	Ligand to PD-ECGFR

IL-1	Ligand to PD-ECGFR
IL-6	Ligand to PD-ECGFR
IL-12	Ligand to PD-ECGFR
PDGF	Ligand to PD-ECGFR
PD-ECGF	Ligand to PD-ECGFR
CXC chemokine	Ligand to PD-ECGFR
CC chemokine	Ligand to PD-ECGFR
C chemokine	Ligand to PD-ECGFR
IL-15	Ligand to PD-ECGFR
TNF- α	Ab to PD-ECGFR
TNF- β	Ab to PD-ECGFR
IFN- α	Ab to PD-ECGFR
IFN- β	Ab to PD-ECGFR
IFN- γ	Ab to PD-ECGFR
IL-2	Ab to PD-ECGFR
IL-12	Ab to PD-ECGFR
EMAP II	Ab to PD-ECGFR
VEGF	Ab to PD-ECGFR
IL-1	Ab to PD-ECGFR
IL-6	Ab to PD-ECGFR
IL-12	Ab to PD-ECGFR
PDGF	Ab to PD-ECGFR
PD-ECGF	Ab to PD-ECGFR
CXC chemokine	Ab to PD-ECGFR
CC chemokine	Ab to PD-ECGFR
C chemokine	Ab to PD-ECGFR
IL-15	Ab to PD-ECGFR
TNF- α	Ligand to TNFR
TNF- β	Ligand to TNFR
IFN- α	Ligand to TNFR
IFN- β	Ligand to TNFR
IFN- γ	Ligand to TNFR
IL-2	Ligand to TNFR
IL-12	Ligand to TNFR
EMAP II	Ligand to TNFR
VEGF	Ligand to TNFR
IL-1	Ligand to TNFR
IL-6	Ligand to TNFR
IL-12	Ligand to TNFR
PDGF	Ligand to TNFR
PD-ECGF	Ligand to TNFR
CXC chemokine	Ligand to TNFR
CC chemokine	Ligand to TNFR

C chemokine	Ligand to TNFR
IL-15	Ligand to TNFR
TNF- α	Ab to TNFR
TNF- β	Ab to TNFR
IFN- α	Ab to TNFR
IFN- β	Ab to TNFR
IFN- γ	Ab to TNFR
IL-2	Ab to TNFR
IL-12	Ab to TNFR
EMAP II	Ab to TNFR
VEGF	Ab to TNFR
IL-1	Ab to TNFR
IL-6	Ab to TNFR
IL-12	Ab to TNFR
PDGF	Ab to TNFR
PD-ECGF	Ab to TNFR
CXC chemokine	Ab to TNFR
CC chemokine	Ab to TNFR
C chemokine	Ab to TNFR
IL-15	Ab to TNFR
TNF- α	Ligand to PDGFR
TNF- β	Ligand to PDGFR
IFN- α	Ligand to PDGFR
IFN- β	Ligand to PDGFR
IFN- γ	Ligand to PDGFR
IL-2	Ligand to PDGFR
IL-12	Ligand to PDGFR
EMAP II	Ligand to PDGFR
VEGF	Ligand to PDGFR
IL-1	Ligand to PDGFR
IL-6	Ligand to PDGFR
IL-12	Ligand to PDGFR
PDGF	Ligand to PDGFR
PD-ECGF	Ligand to PDGFR
CXC chemokine	Ligand to PDGFR
CC chemokine	Ligand to PDGFR
C chemokine	Ligand to PDGFR
IL-15	Ligand to PDGFR
TNF- α	Ab to PDGFR
TNF- β	Ab to PDGFR
IFN- α	Ab to PDGFR
IFN- β	Ab to PDGFR
IFN- γ	Ab to PDGFR

IL-2	Ab to PDGFR
IL-12	Ab to PDGFR
EMAP II	Ab to PDGFR
VEGF	Ab to PDGFR
IL-1	Ab to PDGFR
IL-6	Ab to PDGFR
IL-12	Ab to PDGFR
PDGF	Ab to PDGFR
PD-ECGF	Ab to PDGFR
CXC chemokine	Ab to PDGFR
CC chemokine	Ab to PDGFR
C chemokine	Ab to PDGFR
IL-15	Ab to PDGFR
TNF- α	Ligand to PSMA
TNF- β	Ligand to PSMA
IFN- α	Ligand to PSMA
IFN- β	Ligand to PSMA
IFN- γ	Ligand to PSMA
IL-2	Ligand to PSMA
IL-12	Ligand to PSMA
EMAP II	Ligand to PSMA
VEGF	Ligand to PSMA
IL-1	Ligand to PSMA
IL-6	Ligand to PSMA
IL-12	Ligand to PSMA
PDGF	Ligand to PSMA
PD-ECGF	Ligand to PSMA
CXC chemokine	Ligand to PSMA
CC chemokine	Ligand to PSMA
C chemokine	Ligand to PSMA
IL-15	Ligand to PSMA
TNF- α	Ab to PSMA
TNF- β	Ab to PSMA
IFN- α	Ab to PSMA
IFN- β	Ab to PSMA
IFN- γ	Ab to PSMA
IL-2	Ab to PSMA
IL-12	Ab to PSMA
EMAP II	Ab to PSMA
VEGF	Ab to PSMA
IL-1	Ab to PSMA
IL-6	Ab to PSMA
IL-12	Ab to PSMA

PDGF	Ab to PSMA
PD-ECGF	Ab to PSMA
CXC chemokine	Ab to PSMA
CC chemokine	Ab to PSMA
C chemokine	Ab to PSMA
IL-15	Ab to PSMA
TNF- α	Vitronectin
TNF- β	Vitronectin
IFN- α	Vitronectin
IFN- β	Vitronectin
IFN- γ	Vitronectin
IL-2	Vitronectin
IL-12	Vitronectin
EMAP II	Vitronectin
VEGF	Vitronectin
IL-1	Vitronectin
IL-6	Vitronectin
IL-12	Vitronectin
PDGF	Vitronectin
PD-ECGF	Vitronectin
CXC chemokine	Vitronectin
CC chemokine	Vitronectin
C chemokine	Vitronectin
IL-15	Vitronectin
TNF- α	Laminin
TNF- β	Laminin
IFN- α	Laminin
IFN- β	Laminin
IFN- γ	Laminin
IL-2	Laminin
IL-12	Laminin
EMAP II	Laminin
VEGF	Laminin
IL-1	Laminin
IL-6	Laminin
IL-12	Laminin
PDGF	Laminin
PD-ECGF	Laminin
CXC chemokine	Laminin
CC chemokine	Laminin
C chemokine	Laminin
IL-15	Laminin
TNF- α	Ligand to oncofetal fibronectin

TNF- β	Ligand to oncofetal fibronectin
IFN- α	Ligand to oncofetal fibronectin
IFN- β	Ligand to oncofetal fibronectin
IFN- γ	Ligand to oncofetal fibronectin
IL-2	Ligand to oncofetal fibronectin
IL-12	Ligand to oncofetal fibronectin
EMAP II	Ligand to oncofetal fibronectin
VEGF	Ligand to oncofetal fibronectin
IL-1	Ligand to oncofetal fibronectin
IL-6	Ligand to oncofetal fibronectin
IL-12	Ligand to oncofetal fibronectin
PDGF	Ligand to oncofetal fibronectin
PD-ECGF	Ligand to oncofetal fibronectin
CXC chemokine	Ligand to oncofetal fibronectin
CC chemokine	Ligand to oncofetal fibronectin
C chemokine	Ligand to oncofetal fibronectin
IL-15	Ligand to oncofetal fibronectin
TNF- α	Ab to oncofetal fibronectin
TNF- β	Ab to oncofetal fibronectin
IFN- α	Ab to oncofetal fibronectin
IFN- β	Ab to oncofetal fibronectin
IFN- γ	Ab to oncofetal fibronectin
IL-2	Ab to oncofetal fibronectin
IL-12	Ab to oncofetal fibronectin
EMAP II	Ab to oncofetal fibronectin
VEGF	Ab to oncofetal fibronectin
IL-1	Ab to oncofetal fibronectin
IL-6	Ab to oncofetal fibronectin
IL-12	Ab to oncofetal fibronectin
PDGF	Ab to oncofetal fibronectin
PD-ECGF	Ab to oncofetal fibronectin
CXC chemokine	Ab to oncofetal fibronectin
CC chemokine	Ab to oncofetal fibronectin
C chemokine	Ab to oncofetal fibronectin
IL-15	Ab to oncofetal fibronectin

It will be appreciated that in the above Table the term "Ab" represents antibody, and that the antibodies and ligands include fragments thereof.

In particularly preferred embodiments the conjugate comprises TNF- α or TNF- β and an NGR-containing peptide, or TNF- α or TNF- β and an RGD-containing peptide.

In a preferred embodiment the conjugate is in the form of a fusion protein.

5 In another embodiment the conjugate is in the form of nucleic acid.

In another embodiment the composition further comprises another antitumor agent or diagnostic tumor-imaging compound. Preferably the further antitumor agent is doxorubicin, melphalan or cisplatin.

10

According to another aspect of the present invention there is provided use of a conjugate or a pharmaceutical composition according to the present invention for the preparation of a medicament for treatment or diagnosis of cancer.

15 In other words the present invention provides a method of treating or diagnosing cancer comprising administering to a patient in need of the same a conjugate or a pharmaceutical composition according to the present invention in an effective amount, wherein said amount does not induce a negative feedback mechanism.

20 Some key advantages of the Invention

To reach cancer cells in solid tumors, chemotherapeutic drugs must enter the tumor blood vessels, cross the vessel wall and finally migrate through the interstitium. Heterogeneous tumor perfusion, vascular permeability and cell density, and increased
25 interstitial pressure could represent critical barriers that may limit the penetration of drugs into neoplastic cells distant to from tumor vessels and, consequently, the effectiveness of chemotherapy (1). Strategies aimed at improving drug penetration in tumors are, therefore, of great experimental and clinical interest.

30 A growing body of evidence suggests that Tumor Necrosis Factor- α (TNF), and inflammatory cytokine endowed with potent anti-tumor activity, could be exploited for this purpose. For example, the addition of TNF to regional isolated limb perfusion with melphalan or doxorubicin has produced higher response rates in patients with extremity soft-tissue sarcomas or melanomas than those obtained with

chemotherapeutic drugs alone (2-6). TNF-induced alteration of the endothelial barrier function, reduction of tumor interstitial pressure, increased chemotherapeutic drug penetration and tumor vessel damage are believed to be important mechanisms of the synergy between TNF and chemotherapy (3, 4, 7-10). Unfortunately, systemic administration of TNF is accompanied by prohibitive toxicity, the maximum tolerated dose (8-10 $\mu\text{g/kg}$) being 10-50 times lower than the estimated effective dose (11, 12). For this reason, systemic administration of TNF has been abandoned and the clinical use of this cytokine is limited to locoregional treatments. Nevertheless, some features of the TNF activity, in particular the selectivity for tumor-associated vessels and the synergy with chemotherapeutic drugs, has continued to nourish hopes as regards the possibility of wider therapeutic applications (13).

The vascular effects of TNF provide the rationale for developing a "vascular targeting" strategy aimed at increasing the local efficacy and at enabling systemic administration of therapeutic doses. We have shown recently that targeted delivery of TNF to tumor vessels can be achieved by coupling this protein with the CNGRC peptide, an aminopeptidase N (CD13) ligand that targets the tumor neovasculature (14). In the present work, we have investigated whether vascular targeting with low doses of this conjugate, called NGR-TNF, could enhance the penetration of chemotherapeutic drugs in tumors and improve their efficacy. We show that systemic administration of picogram doses of NGR-TNF (3-5 ng/kg) to mice, six orders of magnitude lower than the LD_{50} , is sufficient to enhance the anti-tumor activity of melphalan and doxorubicin, with no evidence of increased toxicity. In addition, we provide evidence that vascular targeting with NGR-TNF can reduce drug-penetration barriers and increase the amount of doxorubicin that reach cancer cells. Finally, we show that the delivery of minute amounts of NGR-TNF to tumor vessels overcomes another major problem associated with systemic administration of relatively high doses of TNF, i.e. the induction of soluble TNF inhibitors.

Detailed description

Various preferred features and embodiments of the present invention will now be described by way of non-limiting example.

Although in general the techniques mentioned herein are well known in the art, reference may be made in particular to Sambrook *et al.*, Molecular Cloning, A Laboratory Manual (1989) and Ausubel *et al.*, Short Protocols in Molecular Biology (1999) 4th Ed, John Wiley & Sons, Inc (as well as the complete version Current Protocols in
5 Molecular Biology).

Negative Feedback mechanisms

Negative feedback mechanisms are known in the art and may include: soluble
10 receptor shedding and the induction of other cytokines, hormones or biological agents at a systemic or local level such that they directly or indirectly impair the activity of the targeted cytokine of the present invention. The induction of soluble inhibitors or decoy receptors are examples of direct inhibitors. IL-10, TGF- β or other anti-inflammatory cytokines may indirectly prevent the cascade of events triggered by
15 inflammatory cytokines.

Receptor shedding

This term relates to the ability of cells to cleave off the extracellular domain of a
20 cytokine receptor and to release it into circulation as a soluble product. In many instances these cleavage products are still capable of binding their ligands. In contrast, however, the remaining portion of the membrane-bound receptor does not bind ligands any longer and hence the cells become desensibilised to the action of a particular cytokine. Such soluble receptors have been described for a variety of
25 cytokines, including IL-4, 6, 6, IGF, TNF- α and IFN- γ .

Conjugate

The present invention relates to a conjugate which is a molecule comprising at least one targeting protein linked to at least cytokine formed through genetic fusion or
30 chemical coupling. By "linked" we mean that the first and second sequences are associated such that the second sequence is able to be transported by the first sequence to a target cell. Thus, conjugates include fusion proteins in which the transport protein is linked to a cytokine via their polypeptide backbones through

genetic expression of a DNA molecule encoding these proteins, directly synthesised proteins and coupled proteins in which pre-formed sequences are associated by a cross-linking agent. The term is also used herein to include associations, such as aggregates, of the cytokine with the targeting protein. According to one embodiment
5 the second sequence may comprise a polynucleotide sequence. This embodiment may be seen as a protein/nucleic acid complex.

The second sequence may be from the same species as the first sequence, but is present in the conjugate of the invention in a manner different from the natural
10 situation, or from a different species.

The conjugates of the present invention are capable of being directed to a cell so that an effector function corresponding to the polypeptide sequence coupled to the transport sequence can take place.

15

The peptide can be coupled directly to the cytokine or indirectly through a spacer, which can be a single amino acid, an amino acid sequence or an organic residue, such as 6-aminocapryl-N-hydroxysuccinimide.

20 The peptide ligand is preferably linked to the cytokine N-terminus thus minimising any interference in the binding of the modified cytokine to its receptor. Alternatively, the peptide can be linked to amino acid residues which are amido- or carboxylic-bond acceptors, which may be naturally occurring on the molecule or artificially inserted using genetic engineering techniques. The modified cytokine is preferably prepared
25 by use of a cDNA comprising a 5'-contiguous sequence encoding the peptide.

According to a preferred embodiment, there is provided a conjugation product between TNF and the CNGRC sequence in which the amino-terminal of TNF is linked to the CNGRC peptide through the spacer G (glycine).

30

Cytokines

Drug penetration into neoplastic cells is critical for the effectiveness of solid-tumor chemotherapy. To reach cancer cells in solid tumors, chemotherapeutic drugs must enter the drug blood vessels, cross the vessel wall and finally migrate through the interstitium. Heterogeneous tumor perfusion, vascular permeability and cell density, and increased interstitial pressure may represent critical barriers that may limit the penetration of drugs into neoplastic cells and, consequently, the effectiveness of chemotherapy. Cytokines which have the effect of affecting these factors are therefore useful in the present invention. A non-limiting list of cytokines which may be used in the present invention is: $\text{TNF}\alpha$, $\text{TNF}\beta$, $\text{IFN}\alpha$, $\text{IFN}\beta$, $\text{IFN}\gamma$, IL-1, 2, 4, 6, 12, 15, EMAP II, vascular endothelial growth factor (VEGF), PDGF, PD-ECGF or a chemokine.

TNF

TNF acts as an inflammatory cytokine and has the effect of inducing alteration of the endothelial barrier function, reducing of tumor interstitial pressure, and increasing chemotherapeutic drug penetration and tumor vessel damage.

The first suggestion that a tumor necrotizing molecule existed was made when it was observed that cancer patients occasionally showed spontaneous regression of their tumors following bacterial infections. Subsequent studies in the 1960s indicated that host-associated (or endogenous) mediators, manufactured in response to bacterial products, were likely responsible for the observed effects. In 1975 it was shown that a bacterially-induced circulating factor had strong anti-tumor activity against tumors implanted in the skin in mice. This factor, designated tumor necrosis factor (TNF), was subsequently isolated, cloned, and found to be the prototype of a family of molecules that are involved with immune regulation and inflammation. The receptors for TNF and the other members of the TNF superfamily also constitute a superfamily of related proteins.

TNF-related ligands usually share a number of common features. These features do not include a high degree of overall amino acid (aa) sequence homology. With the exception of nerve growth factor (NGF) and TNF-beta, all ligands are synthesised as

type II transmembrane proteins (extracellular C-terminus) that contain a short cytoplasmic segment (10-80 aa residues) and a relatively long extracellular region (140-215 aa residues). NGF, which is structurally unrelated to TNF, is included in this superfamily only because of its ability to bind to the TNFRSF low affinity NGF receptor (LNGFR). NGF has a classic signal sequence peptide and is secreted. TNF- β , in contrast, although also fully secreted, has a primary structure much more related to type II transmembrane proteins. TNF- β might be considered as a type II protein with a non-functional, or inefficient, transmembrane segment. In general, TNFSF members form trimeric structures, and their monomers are composed of beta-strands that orient themselves into a two sheet structure. As a consequence of the trimeric structure of these molecules, it is suggested that the ligands and receptors of the TNFSF and TNFRSF superfamilies undergo "clustering" during signal transduction.

TNF- α : Human TNF- α is a 233 aa residue, nonglycosylated polypeptide that exists as either a transmembrane or soluble protein. When expressed as a 26 kDa membrane bound protein, TNF- α consists of a 29 aa residue cytoplasmic domain, a 28 aa residue transmembrane segment, and a 176 aa residue extracellular region. The soluble protein is created by a proteolytic cleavage event via an 85 kDa TNF-alpha converting enzyme (TACE), which generates a 17 kDa, 157 aa residue molecule that normally circulates as a homotrimer.

TNF- β /LT- α : TNF- β , otherwise known as lymphotoxin- α (LT- α) is a molecule whose cloning was contemporary with that of TNF- α . Although TNF- β circulates as a 171 aa residue, 25 kDa glycosylated polypeptide, a larger form has been found that is 194 aa residues long. The human TNF- β cDNA codes for an open reading frame of 205 aa residues (202 in the mouse), and presumably some type of proteolytic processing occurs during secretion. As with TNF- α , circulating TNF- β exists as a non-covalently linked trimer and is known to bind to the same receptors as TNF- α .

In one embodiment the TNF is a mutant form of TNF capable of selectively binding to one of the TNF receptors (Loetscher H *et al* (1993) J Biol Chem 268:26350-7; Van Ostade X *et al* (1993) Nature 361:266-9).

Many other inflammatory cytokines also have the property of increasing endothelial vessel permeability, and it will be appreciated that the invention can be applied to such cytokines, together with agents which increase expression of such cytokines. Inflammatory cytokines, also known as pro-inflammatory cytokines, are a number of
 5 polypeptides and glycoproteins with molecular weights between 5kDa and 70 kDa. They have a stimulating effect on the inflammatory response. The most important inflammatory cytokines are TNF, IL-1, IL-6 and IL-8.

A Table of some cytokines classified as inflammatory cytokines is shown below:

10

Inflammatory Cytokines

Group	Individual cytokines
Endogenous cytokines	IL-1, TNF- α , IL-6
Up-regulation	IL-1, TNF- α , IL-6, IFN- α , INF- β , chemokines
Stimulation of the production of acute phase reactants	IL-1, IL-6, IL-11, TNF- α , INF- γ , TGF- β , LIF, OSM, CNTF
Chemoattractant cytokines	
CXC chemokines	IL-8, PF-4, PBP, NAP-2, β -TG
CC chemokines	MIP-1 α , MIP-1 β , MCP-1, MCP-2, MCP-3, RANTES
C chemokines	Lymphotactin
Stimulation of inflammatory cytokines	IL-12

TGF- β : transforming growth factor, LIF: leukemia inhibitory factor; OSM: oncostatin M; CNTF: ciliary neurotrophic factor; PF-4: platelet factor 4; PBP: platelet basic
 15 protein; NAP-2: neutrophil activating protein 2; β -TG: β -thromboglobulin; MIP: macrophage inflammatory protein; MCP: monocyte chemoattractant protein.

The up-regulation of inflammatory response is also performed by IL-11, IFN- α , IFN- β , and especially by the members of the chemokine superfamily. TGF- β in some
 20 situations has a number of inflammatory activities including chemoattractant effects on neutrophils, T lymphocytes and inactivated monocytes.

IL-2

Because of the central role of the IL-2/IL-2R system in mediation of the immune and inflammatory responses, it is obvious that monitoring and manipulation of this system has important diagnostic and therapeutic implications. IL-2 has shown promise as an anti-cancer drug by virtue of its ability to stimulate the proliferation and activities of tumor-attacking LAK and TIL (tumor-infiltrating lymphocytes) cells. However, problems with IL-2 toxicity are still of concern and merit investigation. The present invention addresses this problem.

IL-15

Interleukin 15 (IL-15) is a novel cytokine that shares many biological properties with, but lacks amino acid sequence homology to, IL-2. IL-15 was originally identified in media conditioned by a monkey kidney epithelial cell line (CVI/EBNA) based on its mitogenic activity on the murine T cell line, CTLL-2. IL-15 was also independently discovered as a cytokine produced by a human adult T cell leukemia cell line (HuT-102) that stimulated T cell proliferation and was designated IL-T. By virtue of its activity as a stimulator of T cells, NK cells, LAK cells, and TILs, IL-2 is currently in clinical trials testing its potential use in treatments for cancer and for viral infections. Because of its similar biological activities, IL-15 should have similar therapeutic potential.

Chemokines

Chemokines are a superfamily of mostly small, secreted proteins that function in leukocyte trafficking, recruiting, and recirculation. They also play a critical role in many pathophysiological processes such as allergic responses, infectious and autoimmune diseases, angiogenesis, inflammation, tumor growth, and hematopoietic development. Approximately 80 percent of these proteins have from 66 to 78 amino acids (aa) in their mature form. The remainder are larger with additional aa occurring upstream of the protein core or as part of an extended C-terminal segment. All chemokines signal through seven transmembrane domain G-protein coupled

receptors. There are at least seventeen known chemokine receptors, and many of these receptors exhibit promiscuous binding properties whereby several different chemokines can signal through the same receptor.

5 Chemokines are divided into subfamilies based on conserved aa sequence motifs. Most family members have at least four conserved cysteine residues that form two intramolecular disulfide bonds. The subfamilies are defined by the position of the first two cysteine residues:

- 10 • The alpha subfamily, also called the CXC chemokines, have one aa separating the first two cysteine residues. This group can be further subdivided based on the presence or absence of a glu-leu-arg (ELR) aa motif immediately preceding the first cysteine residue. There are currently five CXC-specific receptors and they are designated CXCR1 to CXCR5. The ELR⁺ chemokines bind to CXCR2 and generally act as neutrophil chemoattractants and
15 activators. The ELR- chemokines bind CXCR3 to -5 and act primarily on lymphocytes. At the time of this writing, 14 different human genes encoding CXC chemokines have been reported in the scientific literature with some additional diversity contributed by alternative splicing.
- 20 • In the beta subfamily, also called the CC chemokines, the first two cysteines are adjacent to one another with no intervening aa. There are currently 24 distinct human beta subfamily members. The receptors for this group are designated CCR1 to CCR11. Target cells for different CC family members include most types of leukocytes.
- 25 • There are two known proteins with chemokine homology that fall outside of the alpha and beta subfamilies. Lymphotactin is the lone member of the gamma class (C chemokine) which has lost the first and third cysteines. The lymphotactin receptor is designated XCR1. Fractalkine, the only known member of the delta class (CX₃C chemokine), has three intervening aa between the first two cysteine residues. This molecule is unique among
30 chemokines in that it is a transmembrane protein with the N-terminal chemokine domain fused to a long mucin-like stalk. The fractalkine receptor is known as CX₃CR1.

VEGF

The present invention is also applicable to Vasculature Endothelial Growth Factor (VEGF). Angiogenesis is a process of new blood vessel development from pre-existing vasculature. It plays an essential role in embryonic development, normal growth of tissues, wound healing, the female reproductive cycle (*i.e.*, ovulation, menstruation and placental development), as well as a major role in many diseases. Particular interest has focused on cancer, since tumors cannot grow beyond a few millimeters in size without developing a new blood supply. Angiogenesis is also necessary for the spread and growth of tumor cell metastases.

One of the most important growth and survival factors for endothelium is VEGF. VEGF induces angiogenesis and endothelial cell proliferation and it plays an important role in regulating vasculogenesis. VEGF is a heparin-binding glycoprotein that is secreted as a homodimer of 45 kDa. Most types of cells, but usually not endothelial cells themselves, secrete VEGF. Since the initially discovered VEGF, VEGF-A, increases vascular permeability, it was known as vascular permeability factor. In addition, VEGF causes vasodilatation, partly through stimulation of nitric oxide synthase in endothelial cells. VEGF can also stimulate cell migration and inhibit apoptosis. There are several splice variants of VEGF-A. The major ones include: 121, 165, 189 and 206 amino acids (aa), each one comprising a specific exon addition.

EMAP II

Endothelial-Monocyte Activating Polypeptide-II (EMAP-II) is a cytokine that is an antiangiogenic factor in tumor vascular development, and strongly inhibits tumor growth. Recombinant human EMAP-II is an 18.3 kDa protein containing 166 amino acid residues. EMAP II has also been found to increase endothelial vessel permeability.

PDGF

It has also been proposed that platelet-derived growth factor (PDGF) antagonists might increase drug-uptake and therapeutic effects of a broad range of anti-tumor

agents in common solid tumors. PDGF is a cytokine of 30kDA and is released by platelets on wounding and stimulates nearby cells to grow and repair the wound.

PD-ECGF

5

As its name suggests, platelet-derived endothelial cell growth factor (PD-ECGF) was originally isolated from platelets based on its ability to induce mitosis in endothelial cells. Its related protein is gliostatin.

10 Targeting Moiety

We have found that the therapeutic index of cytokines can be increased by homing of targeting the cytokine to tumor vessels. In addition, since it is known that tumor cells can form part of the lining of tumor vasculature, the present invention
15 encompasses targeting to tumor cells directly as well as to its vasculature. Any convenient tumor or tumor vasculature, particular endothelial cell, targeting moiety may be used in the conjugate of the present invention. Many such targeting moieties are known and these and any which subsequently become available are encompassed within the scope of the present invention. In one embodiment, the targeting moiety is
20 a binding partner, such as a ligand, of a receptor expressed by a tumor cell, or a binding partner, such as an antibody, to a marker or a component of the extracellular matrix associated with tumor cells. More particularly the targeting moiety is binding partner, such as a ligand of, a receptor expressed by tumor-associated vessels, or a binding partner, such as an antibody, to an endothelial marker or a component of the
25 extracellular matrix associated with angiogenic vessels. The term binding partner is used here in its broadest sense and includes both natural and synthetic binding domains, including ligand and antibodies or binding fragments thereof. Thus, said binding partner can be an antibody or a fragment thereof such as Fab, Fv, single-chain Fv, a peptide or a peptido-mimetic, namely a peptido-like molecule capable of
30 binding to the receptor, marker of extracellular component of the cell.

The following represent a non-limiting examples of suitable targeting domains and receptors/markers to which the conjugate may be targeted:

CD13

It has surprisingly been found that the therapeutic index of certain cytokines can be remarkably improved and their immunotherapeutic properties can be enhanced by coupling with a ligand of aminopeptidase-N receptor (CD13). CD13 is a transmembrane glycoprotein of 150 kDa highly conserved in various species. It is expressed on normal cells as well as in myeloid tumor lines, in the angiogenic endothelium and in some epithelia. CD13 receptor is usually identified as "NGR" receptor, in that its peptide ligands share the amino acidic "NGR" motif. The ligand is preferably a straight or cyclic peptide comprising the NGR motif, such as CNGRCSVSGCAGRC, NGRAHA, GNGRG, cycloCVLNGRMEC or cycloCNGRC, or more preferably the peptide. CNGRC. Further details can be found in our WO01/61017 which is incorporated herein by reference.

15 TNF receptor

As with members of the TNF Superfamily, members of the TNF Receptor Superfamily (TNFRSF) also share a number of common features. In particular, molecules in the TNFRSF are all type I (N-terminus extracellular) transmembrane glycoproteins that contain one to six ligand-binding, 40 aa residue cysteine-rich motifs in their extracellular domain. In addition, functional TNFRSF members are usually trimeric or multimeric complexes that are stabilised by intracysteine disulfide bonds. Unlike most members of the TNFSF, TNFRSF members exist in both membrane-bound and soluble forms. Finally, although aa sequence homology in the cytoplasmic domains of the superfamily members does not exceed 25%, a number of receptors are able to transduce apoptotic signals in a variety of cells, suggesting a common function.

CD40: CD40 is a 50 kDa, 277 aa residue transmembrane glycoprotein most often associated with B cell proliferation and differentiation. Expressed on a variety of cell types, human CD40 cDNA encodes a 20 aa residue signal sequence, a 173 aa residue extracellular region, a 22 aa residue transmembrane segment, and a 62 aa residue cytoplasmic domain. There are four cysteine-rich motifs in the extracellular region

that are accompanied by a juxtamembrane sequence rich in serines and threonines. Cells known to express CD40 include endothelial cells.

5 TNFRI/p55/CD120a: TNFRI is a 55 kDa, 455 aa residue transmembrane glycoprotein that is apparently expressed by virtually all nucleated mammalian cells. The molecule has a 190 aa residue extracellular region, a 25 aa residue transmembrane segment, and a 220 aa residue cytoplasmic domain. Both TNF- α and TNF- β bind to TNFRI. Among the numerous cells known to express TNFRI are endothelial cells.

10 TNFRII/p75/CD120b: Human TNFRII is a 75 kDa, 461 aa residue transmembrane glycoprotein originally isolated from a human lung fibroblast library. This receptor consists of a 240 aa residue extracellular region, a 27 aa residue transmembrane segment and a 173 aa residue cytoplasmic domain. Soluble forms of TNFRII have been identified, resulting apparently from proteolytic cleavage by a metalloproteinase
15 termed TRRE (TNF-Receptor Releasing Enzyme). The shedding process appears to be independent of that for soluble TNFRI. Among the multitude of cells known to express TNFRII are endothelial cells.

CD134L/OX40L: OX40, the receptor for OX40L, is a T cell activation marker with
20 limited expression that seems to promote the survival (and perhaps prolong the immune response) of CD4⁺ T cells at sites of inflammation. OX40L also shows limited expression. Currently only activated CD4⁺, CD8⁺ T cells, B cells, and vascular endothelial cells have been reported to express this factor. The human ligand is a 32 kDa, 183 aa residue glycosylated polypeptide that consists of a 21 aa residue
25 cytoplasmic domain, a 23 aa residue transmembrane segment, and a 139 aa residue extracellular region.

VEGF receptor family

30 There are three receptors in the VEGF receptor family. They have the common properties of multiple IgG-like extracellular domains and tyrosine kinase activity. The enzyme domains of VEGF receptor 1 (VEGF R1, also known as Flt-1), VEGF R2 (also known as KDR or Flk-1), and VEGF R3 (also known as Flt-4) are divided by an

inserted sequence. Endothelial cells also express additional VEGF receptors, Neuropilin-1 and Neuropilin-2. VEGF-A binds to VEGF R1 and VEGF R2 and to Neuropilin-1 and Neuropilin-2. PlGF and VEGF-B bind VEGF R1 and Neuropilin-1. VEGF-C and -D bind VEGF R3 and VEGF R2. HIV-tat and peptides derived
5 therefrom have also been found to target the VEGFR.

PDGF receptors

PDGF receptors are expressed in the stromal compartment in most common solid
10 tumors. Inhibition of stromally expressed PDGF receptors in a rat colon carcinoma model reduces the tumor interstitial fluid pressure and increases tumor transcapillary transport.

PSMA

15

Prostate specific membrane antigen (PSMA) is also an excellent tumor endothelial marker, and PSMA antibodies can be generated.

Cell adhesion molecules (CAMs)

20

Cell adhesion molecules (CAMs) are cell surface proteins involved in the binding of cells, usually leukocytes, to each other, to endothelial cells, or to extracellular matrix. Specific signals produced in response to wounding and infection control the expression and activation of certain of these adhesion molecules. The interactions and
25 responses then initiated by binding of these CAMs to their receptors/ligands play important roles in the mediation of the inflammatory and immune reactions that constitute one line of the body's defence against these insults. Most of the CAMs characterised so far fall into three general families of proteins: the immunoglobulin (Ig) superfamily, the integrin family, or the selectin family.

30

A member of the Selectin family of cell surface molecules, L-Selectin consists of an NH2-terminal lectin type C domain, an EGF-like domain, two complement control domains, a 15 amino acid residue spacer, a transmembrane sequence and a short cytoplasmic domain.

Three ligands for L-Selectin on endothelial cells have been identified, all containing O-glycosylated mucin or mucin-like domains. The first ligand, GlyCAM-1, is expressed almost exclusively in peripheral and mesenteric lymph node high endothelial venules. The second L-Selectin ligand, originally called sgp90, has now been shown to be CD34. This sialomucin-like glycoprotein, often used as a surface marker for the purification of pluripotent stem cells, shows vascular expression in a wide variety of nonlymphoid tissues, as well as on the capillaries of peripheral lymph nodes. The third ligand for L-Selectin is MadCAM 1, a mucin-like glycoprotein found on mucosal lymph node high endothelial venules.

P-Selectin, a member of the Selectin family of cell surface molecules, consists of an NH₂-terminal lectin type C domain, an EGF-like domain, nine complement control domains, a transmembrane domain, and a short cytoplasmic domain.

The tetrasaccharide sialyl Lewis^x (sLex) has been identified as a ligand for both P- and E-Selectin, but P- E- and L-Selectin can all bind sLex and sLea under appropriate conditions. P-Selectin also reportedly binds selectively to a 160 kDa glycoprotein present on murine myeloid cells and to a glycoprotein on myeloid cells, blood neutrophils, monocytes, and lymphocytes termed P-Selectin glycoprotein ligand-1 (PSGL-1), a ligand that also can bind E-Selectin. P-Selectin-mediated rolling of leukocytes can be completely inhibited by a monoclonal antibody specific for PSGL-1, suggesting that even though P-Selectin can bind to a variety of glycoproteins under *in vitro* conditions, it is likely that physiologically important binding is more limited. A variety of evidence indicates that P-Selectin is involved in the adhesion of myeloid cells, as well as B and a subset of T cells, to activated endothelium.

Ig superfamily CAMs

The Ig superfamily CAMs are calcium-independent transmembrane glycoproteins. Members of the Ig superfamily include the intercellular adhesion molecules (ICAMs), vascular-cell adhesion molecule (VCAM-1), platelet-endothelial-cell adhesion molecule (PECAM-1), and neural-cell adhesion molecule (NCAM). Each Ig superfamily CAM has an extracellular domain, which contains several Ig-like

intrachain disulfide-bonded loops with conserved cysteine residues, a transmembrane domain, and an intracellular domain that interacts with the cytoskeleton. Typically, they bind integrins or other Ig superfamily CAMs. The neuronal CAMs have been implicated in neuronal patterning. Endothelial CAMs play an important role in immune response and inflammation.

In more detail, vascular cell adhesion molecule (VCAM-1, CD106, or INCAM-110), platelet endothelial cell adhesion molecule (PECAM-1/CD31) and intercellular adhesion molecules 1, 2 & 3 (ICAM-1, 2 & 3) are five functionally related CAM/IgSF molecules that are critically involved in leukocyte-connective tissue/endothelial cell interactions. Expressed principally on endothelial cells, these molecules in general regulate leukocyte migration across blood vessel walls and provide attachment points for developing endothelium during angiogenesis and are all suitable for targeting in the present invention.

Human CD31 is a 130 kDa, type I (extracellular N-terminus) transmembrane glycoprotein that belongs to the cell adhesion molecule (CAM) or C2-like subgroup of the IgSF. The mature molecule is 711 amino acid (aa) residues in length and contains a 574 aa residue extracellular region, a 19 aa residue transmembrane segment, and a 118 aa residue cytoplasmic tail. In the extracellular region, there are nine potential N-linked glycosylation sites, and, with a predicted molecular weight of 80 kDa, it appears many of these sites are occupied. The most striking feature of the extracellular region is the presence of six Ig-homology units that resemble the C2 domains of the IgSF. Although they vary in number, the presence of these modules is a common feature of all IgSF adhesion molecules (ICAM-1, 2, 3 & VCAM-1).

Integrins

Integrins are non-covalently linked heterodimers of α and β subunits. To date, 16 α subunits and 8 β subunits have been identified. These can combine in various ways to form different types of integrin receptors. The ligands for several of the integrins are adhesive extracellular matrix (ECM) proteins such as fibronectin, vitronectin, collagens and laminin. Many integrins recognise the amino acid sequence RGD

(arginine-glycine-aspartic acid) which is present in fibronectin or the other adhesive proteins to which they bind. Peptides and protein fragments containing the RGD sequence can be used to modulate the activities of the RGD-recognising integrins. Thus the present invention may employ as the targeting moiety peptides recognised
5 by integrins. These peptides are conventionally known as "RGD-containing peptides". These peptides may include peptide motifs which have been identified as binding to integrins. These motifs include the amino acid sequences: DGR, NGR and CRGDC. The peptide motifs may be linear or cyclic. Such motifs are described in more detail in the following patents which are herein incorporated by reference in
10 relation to their description of an RGD peptides: US Patent 5,536,814 which describes cyclized CRGDCL, CRGDCA and GACRGDCLGA. US Patent 4,578,079 relates to synthetic peptides of formula X-RGD-T/C-Y where X and Y are amino acids. US Patent 5,547,936 describes a peptide containing the sequence X-RGD-XX where X may be an amino acid. US Patent 4,988,621 describes a number of
15 RGD-containing peptides. US Patent 4,879,237 describes a general peptide of the formula RGD-Y where Y is an amino acid, and the peptide G-RGD-AP. US Patent 5,169,930 describes the peptide RGDSPK which binds to $\alpha v \beta 1$ integrin. US Patents 5,498,694 and 5,700,908 relate to the cytoplasmic domain of the $\beta 3$ integrin sub-unit that strictly speaking is not an RGD-containing peptide; although it does contain the
20 sequence RDG. WO97/08203 describes cyclic peptides that are structural mimics or RGD-binding sites. US Patent 5,612,311 describes 15 RGD-containing peptides that are capable of being cyclized either by C-C linkage or through other groups such as penicillamine or mercapto propionic acid analogs. US Patent 5,672,585 describes a general formula encompassing RGD-containing peptides. A preferred group of
25 peptides are those where the aspartic acid residue of RGD is derivatised into an O-methoxy tyrosine derivative. US Patent 5,120,829 describes an RGD cell attachment promoting binding site and a hydrophobic attachment domain. The D form is described in US Patent 5,587,456. US Patent 5,648,330 describes a cyclic RGD-containing peptide that has high affinity for GP IIB/IIIa.

30

In a preferred embodiment of the present invention the targeting moiety is a ligand for $\alpha v \beta 3$ or $\alpha v \beta 5$ integrin.

Activin

Cells known to express ActRII include endothelial cells. ActRIIB expression parallels that for ActRII, and is again found in endothelial cells. Cells known to express ActRI
5 include vascular endothelial cells. ActRII has also been identified in endothelial cells.

Angiogenin

10 Angiogenin (ANG) is a 14 kDa, non-glycosylated polypeptide so named for its ability to induce new blood vessel growth.

Annexin V

15 Annexin V is a member of a calcium and phospholipid binding family of proteins with vascular anticoagulant activity. Various synonyms for Annexin V exist: placental protein 4 (PP4), placental anticoagulant protein I (PAP I), calphobindin I (CPB-I), calcium dependent phospholipid binding protein 33 (CaBP33), vascular anticoagulant protein alpha (VACa), anchorin CII, lipocortin-V, endonexin II, and
20 thromboplastin inhibitor. The number of binding sites for Annexin V has been reported as $6 - 24 \times 10^6/\text{cell}$ in tumor cells and $8.8 \times 10^6/\text{cell}$ for endothelial cells.

CD44

25 Another molecule apparently involved in white cell adhesive events is CD44, a molecule ubiquitously expressed on both hematopoietic and non-hematopoietic cells. CD44 is remarkable for its ability to generate alternatively spliced forms, many of which differ in their activities. This remarkable flexibility has led to speculation that CD44, via its changing nature, plays a role in some of the methods that tumor cells
30 use to progress successfully through growth and metastasis. CD44 is a 80-250 kDa type I (extracellular N-terminus) transmembrane glycoprotein. Cells known to express CD44H include vascular endothelial cells.

There are multiple ligands for CD44, including osteopontin, fibronectin, collagen types I and IV and hyaluronate. Binding to fibronectin is reported to be limited to CD44 variants expressing chondroitin sulfate, with the chondroitin sulfate attachment site localised to exons v8-v11. Hyaluronate binding is suggested to be possible for virtually all CD44 isoforms. One of the principal binding sites is proposed to be centred in exon 2 and to involve lysine and arginine residues. Factors other than the simple expression of a known hyaluronate-binding motif also appear to be necessary for hyaluronate binding. Successful hyaluronate binding is facilitated by the combination of exons expressed, a distinctive cytoplasmic tail, glycosylation patterns, and the activity state of the cell. Thus, in terms of its hyaluronate-binding function, a great deal of "potential" flexibility exists within each CD44-expressing cell.

Fibroblast growth factor (FGF)

15

The name "fibroblast growth factor" (FGF) is a limiting description for this family of cytokines. The function of FGFs is not restricted to cell growth. Although some of the FGFs do, indeed, induce fibroblast proliferation, the original FGF molecule (FGF-2 or FGF basic) is now known to also induce proliferation of endothelial cells, chondrocytes, smooth muscle cells, melanocytes, as well as other cells. It can also promote adipocyte differentiation, induce macrophage and fibroblast IL-6 production, stimulate astrocyte migration, and prolong neuronal survival. To date, the FGF superfamily consists of 23 members, all of which contain a conserved 120 amino acid (aa) core region that contains six identical, interspersed amino acids.

25

FGF-1: Human FGF-1 (also known as FGF acidic, FGFa, ECGF and HBGF-1) is a 17-18 kDa non- glycosylated polypeptide that is expressed by a variety of cells from all three germ layers. The binding molecule may be either an FGF receptor. Cells known to express FGF-1 include endothelial cells.

30

FGF-2: Human FGF-2, otherwise known as FGF basic, HBGF-2, and EDGF, is an 18 kDa, non-glycosylated polypeptide that shows both intracellular and extracellular activity. Following secretion, FGF-2 is sequestered on either cell surface HS or matrix glycosaminoglycans. Although FGF-2 is secreted as a monomer, cell surface HS

seems to dimerize monomeric FGF-2 in a non-covalent side-to-side configuration that is subsequently capable of dimerizing and activating FGF receptors. Cells known to express FGF-2 include endothelial cells.

- 5 FGF-3: Human FGF-3 is the product of the *int-2* gene [*i.e.*, derived from *integration* region-2, a region on mouse chromosome 7 that contains a gene (*int-2*/FGF-3) accidentally activated following retroviral insertion]. The molecule is synthesised as a 28-32 kDa, 222 aa glycoprotein that contains a number of peptide motifs. Cells reported to express FGF-3 are limited to developmental cells and tumors. Tumors
10 known to express FGF-3 include breast carcinomas and colon cancer cell lines.

FGF-4: Human FGF-4 is a 22 kDa, 176 aa glycoprotein that is the product of a developmentally-regulated gene. The molecule is synthesised as a 206 aa precursor that contains a large, ill-defined 30 aa signal sequence plus two heparin-binding
15 motifs (at aa 51-55 and 140-143). The heparin-binding sites directly relate to FGF-4 activity; heparin/heparan regulate the ability of FGF-4 to activate FGFR1 and FGFR2. Cells known to express FGF-4 include both tumor cells and embryonic cells. Its identification in human stomach cancer gives rise to one alternative designation (*/hst-1/hst*), while its isolation in Kaposi's sarcoma provides grounds for another (K-FGF).

20

IL-1R

IL-1 exerts its effects by binding to specific receptors. Two distinct IL-1 receptor binding proteins, plus a non-binding signalling accessory protein have been identified.
25 Each have three extracellular immunoglobulin-like (Ig-like) domains, qualifying them for membership in the type IV cytokine receptor family. The two receptor binding proteins are termed type I IL-1 receptor (IL-1 RI) and type II IL-1 receptor (IL-1 RII) respectively. Human IL-1 RI is a 552 aa, 80 kDa transmembrane glycoprotein that has been isolated from endothelium cells.

30

RTK

The new family of receptor tyrosine kinase (RTK), the Eph receptors and their ligands ephrins, have been found to be involved in vascular assembly, angiogenesis,

tumorigenesis, and metastasis. It has also been that class A Eph receptors and their ligands are elevated in tumor and associated vasculature.

MMP

5

Matrix metalloproteinases (MMPs) have been implicated in tumor growth, angiogenesis, invasion, and metastasis. They have also been suggested for use as tumor markers.

10 NG2

NG2 is a large, integral membrane, chondroitin sulfate proteoglycan that was first identified as a cell surface molecule expressed by immature neural cells. Subsequently NG2 was found to be expressed by a wide variety of immature cells as well as several
15 types of tumors with high malignancy. NG2 has been suggested as a target molecule in the tumor vasculature. In particular, collagenase-1 (CI) is the predominant matrix metalloproteinase present in newly formed microvessels and serves as a marker of neovascularization.

20 Oncofetal fibronectin

The expression of the oncofetal fragment of fibronectin (Fn-f) has also been found to be increased during angiogenesis and has been suggested as a marker of tumor angiogenesis. In one embodiment the TTM is an antibody or fragment thereof to the
25 oncofetal ED-B domain of fibronectin. The preparation of such an antibody and its conjugation with IL-12 is described in Halin *et al* (2002) Nature Biotechnology 20:264-269.

Tenascin

30

Tenascin is a matrix glycoprotein seen in malignant tumors including brain and breast cancers and melanoma. Its expression is malignant but not well differentiated tumors and association with the blood vessels of tumors makes it an important target for both

understanding the biology of malignant tumors and angiogenesis, but is a therapeutic cancer target and marker as well.

5 The targeting moiety is preferably a polypeptide which is capable of binding to a tumor cell or tumor vasculature surface molecule. As well as those mentioned above other such surface molecules which are known or become available may also be targeted by the first sequence.

10 It will be appreciated that one can apply conventional protein binding assays to identify molecules which bind to surface molecules. It will also be appreciated that one can apply structural-based drug design to develop sequences which bind to surface molecules.

15 High throughput screening, as described above for synthetic compounds, can also be used for identifying targeting molecules.

This invention also contemplates the use of competitive drug screening assays in which neutralising antibodies capable of binding a target specifically compete with a test compound for binding to a target.

20

Binding Partner (BP)

The targeting moiety generally take the form of a binding partner (BP) to a surface molecule comprising or consisting of one or more binding domains.

25

Ligand

30 The targeting moiety of the present invention may take the form of a ligand. The ligands may be natural or synthetic. The term "ligand" also refers to a chemically modified ligand. The one or more binding domains of the BP may consist of, for example, a natural ligand for a receptor, which natural ligand may be an adhesion molecule or a growth-factor receptor ligand (e.g. epidermal growth factor), or a fragment of a natural ligand which retains binding affinity for the receptor.

Synthetic ligands include the designer ligands. As used herein, the term means "designer ligands" refers to agents which are likely to bind to the receptor based on their three dimensional shape compared to that of the receptor.

5 Antibodies

Alternatively, the binding domains may be derived from heavy and light chain sequences from an immunoglobulin (Ig) variable region. Such a variable region may be derived from a natural human antibody or an antibody from another species such as
10 a rodent antibody. Alternatively the variable region may be derived from an engineered antibody such as a humanised antibody or from a phage display library from an immunised or a non-immunised animal or a mutagenised phage-display library. As a second alternative, the variable region may be derived from a single-chain variable fragment (scFv). The BP may contain other sequences to achieve
15 multimerisation or to act as spacers between the binding domains or which result from the insertion of restriction sites in the genes encoding the BP, including Ig hinge sequences or novel spacers and engineered linker sequences.

The BP may comprise, in addition to one or more immunoglobulin variable regions,
20 all or part of an Ig heavy chain constant region and so may comprise a natural whole Ig, an engineered Ig, an engineered Ig-like molecule, a single-chain Ig or a single-chain Ig-like molecule. Alternatively, or in addition, the BP may contain one or more domains from another protein such as a toxin.

25 As used herein, an "antibody" refers to a protein consisting of one or more polypeptides substantially encoded by immunoglobulin genes or fragments of immunoglobulin genes. Antibodies may exist as intact immunoglobulins or as a number of fragments, including those well-characterised fragments produced by digestion with various peptidases. While various antibody fragments are defined in
30 terms of the digestion of an intact antibody, one of skill will appreciate that antibody fragments may be synthesised *de novo* either chemically or by utilising recombinant DNA methodology. Thus, the term antibody, as used herein also includes antibody fragments either produced by the modification of whole antibodies or synthesised *de novo* using recombinant DNA methodologies. Antibody fragments encompassed by

the use of the term "antibodies" include, but are not limited to, Fab, Fab', F (ab')₂, scFv, Fv, dsFv diabody, and Fd fragments.

The invention also provides monoclonal or polyclonal antibodies to the surface proteins.
5 Thus, the present invention further provides a process for the production of monoclonal or polyclonal antibodies to polypeptides of the invention.

If polyclonal antibodies are desired, a selected mammal (e.g., mouse, rabbit, goat, horse, etc.) is immunised with an immunogenic polypeptide bearing an epitope(s).
10 Serum from the immunised animal is collected and treated according to known procedures. If serum containing polyclonal antibodies to an epitope contains antibodies to other antigens, the polyclonal antibodies can be purified by immunoaffinity chromatography. Techniques for producing and processing polyclonal antisera are known in the art. In order that such antibodies may be made, the invention
15 also provides polypeptides of the invention or fragments thereof haptenised to another polypeptide for use as immunogens in animals or humans.

Monoclonal antibodies directed against binding cell surface epitopes in the polypeptides can also be readily produced by one skilled in the art. The general
20 methodology for making monoclonal antibodies by hybridomas is well known. Immortal antibody-producing cell lines can be created by cell fusion, and also by other techniques such as direct transformation of B lymphocytes with oncogenic DNA, or transfection with Epstein-Barr virus. Panels of monoclonal antibodies produced against epitopes can be screened for various properties; i.e., for isotype and
25 epitope affinity.

An alternative technique involves screening phage display libraries where, for example the phage express scFv fragments on the surface of their coat with a large variety of complementarity determining regions (CDRs). This technique is well
30 known in the art.

For the purposes of this invention, the term "antibody", unless specified to the contrary, includes fragments of whole antibodies which retain their binding activity for a target antigen. As mentioned above such fragments include Fv, F(ab') and F(ab')₂ fragments, as

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well as single chain antibodies (scFv). Furthermore, the antibodies and fragments thereof may be humanised antibodies, for example as described in EP-A-239400.

Screens

5

In one aspect, the invention relates to a method of screening for an agent capable of binding to a tumor or tumor vasculature cell surface molecule, the method comprising contacting the cell surface molecule with an agent and determining if said agent binds to said cell surface molecule.

10

As used herein, the term "agent" includes, but is not limited to, a compound, such as a test compound, which may be obtainable from or produced by any suitable source, whether natural or not. The agent may be designed or obtained from a library of compounds which may comprise peptides, as well as other compounds, such as small organic molecules and particularly new lead compounds. By way of example, the agent may be a natural substance, a biological macromolecule, or an extract made from biological materials such as bacteria, fungi, or animal (particularly mammalian) cells or tissues, an organic or an inorganic molecule, a synthetic test compound, a semi-synthetic test compound, a structural or functional mimetic, a peptide, a peptidomimetics, a derivatised test compound, a peptide cleaved from a whole protein, or a peptides synthesised synthetically (such as, by way of example, either using a peptide synthesizer) or by recombinant techniques or combinations thereof, a recombinant test compound, a natural or a non-natural test compound, a fusion protein or equivalent thereof and mutants, derivatives or combinations thereof.

25

The agent can be an amino acid sequence or a chemical derivative thereof. The substance may even be an organic compound or other chemical. The agent may even be a nucleotide sequence - which may be a sense sequence or an anti-sense sequence.

30 Protein

The term "protein" includes single-chain polypeptide molecules as well as multiple-polypeptide complexes where individual constituent polypeptides are linked by

covalent or non-covalent means. The term "polypeptide" includes peptides of two or more amino acids in length, typically having more than 5, 10 or 20 amino acids.

Polypeptide homologues

5

It will be understood that polypeptide sequences for use in the invention are not limited to the particular sequences or fragments thereof but also include homologous sequences obtained from any source, for example related viral/bacterial proteins, cellular homologues and synthetic peptides, as well as variants or derivatives thereof.

10 Polypeptide sequences of the present invention also include polypeptides encoded by polynucleotides of the present invention.

Polypeptide Variants, Derivatives and Fragments

15 The terms "variant" or "derivative" in relation to the amino acid sequences of the present invention includes any substitution of, variation of, modification of, replacement of, deletion of or addition of one (or more) amino acids from or to the sequence providing the resultant amino acid sequence preferably has targeting activity, preferably having at least 25 to 50% of the activity as the polypeptides presented in the sequence listings,
20 more preferably at least substantially the same activity.

Thus, sequences may be modified for use in the present invention. Typically, modifications are made that maintain the activity of the sequence. Thus, in one embodiment, amino acid substitutions may be made, for example from 1, 2 or 3 to 10,
25 20 or 30 substitutions provided that the modified sequence retains at least about 25 to 50% of, or substantially the same activity. However, in an alternative embodiment, modifications to the amino acid sequences of a polypeptide of the invention may be made intentionally to reduce the biological activity of the polypeptide. For example truncated polypeptides that remain capable of binding to target molecule but lack
30 functional effector domains may be useful.

In general, preferably less than 20%, 10% or 5% of the amino acid residues of a variant or derivative are altered as compared with the corresponding region depicted in the sequence listings.

Amino acid substitutions may include the use of non-naturally occurring analogues, for example to increase blood plasma half-life of a therapeutically administered polypeptide (see below for further details on the production of peptide derivatives for use in therapy).

Conservative substitutions may be made, for example according to the Table below. Amino acids in the same block in the second column and preferably in the same line in the third column may be substituted for each other:

ALIPHATIC	Non-polar	G A P
		I L V
	Polar - uncharged	C S T M
		N Q
	Polar - charged	D E
		K R
AROMATIC		H F W Y

Polypeptides of the invention also include fragments of the above mentioned polypeptides and variants thereof, including fragments of the sequences. Preferred fragments include those which include an epitope. Suitable fragments will be at least about 5, e.g. 10, 12, 15 or 20 amino acids in length. They may also be less than 200, 100 or 50 amino acids in length. Polypeptide fragments of the proteins and allelic and species variants thereof may contain one or more (e.g. 2, 3, 5, or 10) substitutions, deletions or insertions, including conserved substitutions. Where substitutions, deletion and/or insertions have been made, for example by means of recombinant technology, preferably less than 20%, 10% or 5% of the amino acid residues depicted in the sequence listings are altered.

Proteins of the invention are typically made by recombinant means, for example as described below. However they may also be made by synthetic means using techniques well known to skilled persons such as solid phase synthesis. Various techniques for chemical synthesising peptides are reviewed by Borgia and Fields,
5 2000, TibTech 18: 243-251 and described in detail in the references contained therein.

Therapeutic peptides

Peptides of the present invention may be administered therapeutically to patients. It is
10 preferred to use peptides that do not consisting solely of naturally-occurring amino acids but which have been modified, for example to reduce immunogenicity, to increase circulatory half-life in the body of the patient, to enhance bioavailability and/or to enhance efficacy and/or specificity.

15 A number of approaches have been used to modify peptides for therapeutic application. One approach is to link the peptides or proteins to a variety of polymers, such as polyethylene glycol (PEG) and polypropylene glycol (PPG) – see for example U.S. Patent Nos. 5,091,176, 5,214,131 and US 5,264,209.

20 Replacement of naturally-occurring amino acids with a variety of uncoded or modified amino acids such as D-amino acids and N-methyl amino acids may also be used to modify peptides

Another approach is to use bifunctional crosslinkers, such as N-succinimidyl 3-(2
25 pyridyldithio) propionate, succinimidyl 6-[3-(2 pyridyldithio) propionamido] hexanoate, and sulfosuccinimidyl 6-[3-(2 pyridyldithio) propionamido]hexanoate (see US Patent 5,580,853).

It may be desirable to use derivatives of the peptides of the invention which are
30 conformationally constrained. Conformational constraint refers to the stability and preferred conformation of the three-dimensional shape assumed by a peptide. Conformational constraints include local constraints, involving restricting the conformational mobility of a single residue in a peptide; regional constraints, involving restricting the conformational mobility of a group of residues, which

residues may form some secondary structural unit; and global constraints, involving the entire peptide structure.

The active conformation of the peptide may be stabilised by a covalent modification, such as cyclization or by incorporation of gamma-lactam or other types of bridges. For example, side chains can be cyclized to the backbone so as create a L-gamma-lactam moiety on each side of the interaction site. See, generally, Hruby et al., "Applications of Synthetic Peptides," in *Synthetic Peptides: A User's Guide*: 259-345 (W. H. Freeman & Co. 1992). Cyclization also can be achieved, for example, by formation of cysteine bridges, coupling of amino and carboxy terminal groups of respective terminal amino acids, or coupling of the amino group of a Lys residue or a related homolog with a carboxy group of Asp, Glu or a related homolog. Coupling of the .alpha-amino group of a polypeptide with the epsilon-amino group of a lysine residue, using iodoacetic anhydride, can be also undertaken. See Wood and Wetzel, 1992, *Int'l J. Peptide Protein Res.* 39: 533-39.

Another approach described in US 5,891,418 is to include a metal-ion complexing backbone in the peptide structure. Typically, the preferred metal-peptide backbone is based on the requisite number of particular coordinating groups required by the coordination sphere of a given complexing metal ion. In general, most of the metal ions that may prove useful have a coordination number of four to six. The nature of the coordinating groups in the peptide chain includes nitrogen atoms with amine, amide, imidazole, or guanidino functionalities; sulfur atoms of thiols or disulfides; and oxygen atoms of hydroxy, phenolic, carbonyl, or carboxyl functionalities. In addition, the peptide chain or individual amino acids can be chemically altered to include a coordinating group, such as for example oxime, hydrazino, sulfhydryl, phosphate, cyano, pyridino, piperidino, or morpholino. The peptide construct can be either linear or cyclic, however a linear construct is typically preferred. One example of a small linear peptide is Gly-Gly-Gly-Gly which has four nitrogens (an N₄ complexation system) in the back bone that can complex to a metal ion with a coordination number of four.

A further technique for improving the properties of therapeutic peptides is to use non-peptide peptidomimetics. A wide variety of useful techniques may be used to

elucidating the precise structure of a peptide. These techniques include amino acid sequencing, x-ray crystallography, mass spectroscopy, nuclear magnetic resonance spectroscopy, computer-assisted molecular modelling, peptide mapping, and combinations thereof. Structural analysis of a peptide generally provides a large body of data which comprise the amino acid sequence of the peptide as well as the three-dimensional positioning of its atomic components. From this information, non-peptide peptidomimetics may be designed that have the required chemical functionalities for therapeutic activity but are more stable, for example less susceptible to biological degradation. An example of this approach is provided in US 5,811,512.

10

Techniques for chemically synthesising therapeutic peptides of the invention are described in the above references and also reviewed by Borgia and Fields, 2000, TibTech 18: 243-251 and described in detail in the references contained therein.

15 Bifunctional derivatives

A further embodiment of the invention is provided by bifunctional derivatives in which the cytokines modified with a TTM are conjugated with antibodies, or their fragments, against tumoral antigens or other tumor angiogenic markers, e.g. α v integrins, metalloproteases or the vascular growth factor, or antibodies or fragments thereof directed against components of the extracellular matrix, such as anti-tenascin antibodies or anti-fibronectin EDB domain. The preparation of a fusion product between TNF and the hinge region of a mAb against the tumor-associated TAG72 antigen expressed by gastric and ovarian adenocarcinoma has recently been reported .

25

A further embodiment of the invention is provided by the tumoral pre-targeting with the biotin/avidin system. According to this approach, a ternary complex is obtained on the tumoral antigenic site, at different stages, which is formed by 1) biotinylated mAb, 2) avidin (or streptavidin) and 3) bivalent cytokine modified with the TTM and biotin. A number of papers proved that the pre-targeting approach, compared with conventional targeting with immunoconjugates, can actually increase the ratio of active molecule homed at the target to free active molecule, thus reducing the treatment toxicity. This approach produced favorable results with biotinylated TNF,

30

which was capable of inducing cytotoxicity *in vitro* and decreasing the tumor cells growth under conditions in which normal TNF was inactive. The pre-targeting approach can also be carried out with a two-phase procedure by using a bispecific antibody which at the same time binds the tumoral antigen and the modified cytokine.

- 5 The use of a bispecific antibody directed against a carcinoembryonic antigen and TNF has recently been described as a means for TNF tumoral pre-targeting.

According to a further embodiment, the invention comprises a cytokine conjugated to both a TTM and an antibody, or a fragment thereof (directly or indirectly via a boitin-
10 avidin bridge), on different TNF subunits, where the antibody or its fragments are directed against an antigen expressed on tumor cells or other components of the tumor stroma, e.g. tenacin and fibronectin EDB domain. This results in a further improvement of the tumor homing properties of the modified cytokine and in the slow release of the latter in the tumor microenvironment through trimer-monomer-trimer
15 transitions. The modified subunits of e.g. TNF conjugates can disassociate from the targeting complexes and reassociate so as to form unmodified trimeric TNF molecules, which then diffuse in the tumor microenvironment. The release of bioactive TNF has been shown to occur within 24-48 hours after targeting.

- 20 The preparation of cytokines in the form of liposomes can improve the biological activity thereof. It has, in fact, been observed that acylation of the TNF amino groups induces an increase in its hydrophobicity without loss of biological activity *in vitro*. Furthermore, it has been reported that TNF bound to lipids has unaffected cytotoxicity *in vitro*, immunomodulating effects and reduced toxicity *in vivo*.

25

Polynucleotides

- Polynucleotides for use in the invention comprise nucleic acid sequences encoding the polypeptide conjugate of the invention. It will be understood by a skilled person that
30 numerous different polynucleotides can encode the same polypeptide as a result of the degeneracy of the genetic code. In addition, it is to be understood that skilled persons may, using routine techniques, make nucleotide substitutions that do not affect the polypeptide sequence encoded by the polynucleotides of the invention to reflect the

codon usage of any particular host organism in which the polypeptides of the invention are to be expressed.

Polynucleotides of the invention may comprise DNA or RNA. They may be single-stranded or double-stranded. They may also be polynucleotides which include within
5 them synthetic or modified nucleotides. A number of different types of modification to oligonucleotides are known in the art. These include methylphosphonate and phosphorothioate backbones, addition of acridine or polylysine chains at the 3' and/or 5' ends of the molecule. For the purposes of the present invention, it is to be
10 understood that the polynucleotides described herein may be modified by any method available in the art. Such modifications may be carried out in order to enhance the *in vivo* activity or life span of polynucleotides of the invention.

Nucleotide vectors

15

Polynucleotides of the invention can be incorporated into a recombinant replicable vector. The vector may be used to replicate the nucleic acid in a compatible host cell. Thus in a further embodiment, the invention provides a method of making polynucleotides of the invention by introducing a polynucleotide of the invention into
20 a replicable vector, introducing the vector into a compatible host cell, and growing the host cell under conditions which bring about replication of the vector. The vector may be recovered from the host cell. Suitable host cells include bacteria such as *E. coli*, yeast, mammalian cell lines and other eukaryotic cell lines, for example insect Sf9 cells.

25

Preferably, a polynucleotide of the invention in a vector is operably linked to a control sequence that is capable of providing for the expression of the coding sequence by the host cell, i.e. the vector is an expression vector. The term "operably linked" means that the components described are in a relationship permitting them to function in
30 their intended manner. A regulatory sequence "operably linked" to a coding sequence is ligated in such a way that expression of the coding sequence is achieved under condition compatible with the control sequences.

The control sequences may be modified, for example by the addition of further

transcriptional regulatory elements to make the level of transcription directed by the control sequences more responsive to transcriptional modulators.

Vectors of the invention may be transformed or transfected into a suitable host cell as described below to provide for expression of a protein of the invention. This process may comprise culturing a host cell transformed with an expression vector as described above under conditions to provide for expression by the vector of a coding sequence encoding the protein, and optionally recovering the expressed protein.

The vectors may be for example, plasmid or virus vectors provided with an origin of replication, optionally a promoter for the expression of the said polynucleotide and optionally a regulator of the promoter. The vectors may contain one or more selectable marker genes, for example an ampicillin resistance gene in the case of a bacterial plasmid or a neomycin resistance gene for a mammalian vector. Vectors may be used, for example, to transfect or transform a host cell.

Control sequences operably linked to sequences encoding the protein of the invention include promoters/enhancers and other expression regulation signals. These control sequences may be selected to be compatible with the host cell for which the expression vector is designed to be used in. The term "promoter" is well-known in the art and encompasses nucleic acid regions ranging in size and complexity from minimal promoters to promoters including upstream elements and enhancers.

The promoter is typically selected from promoters which are functional in mammalian cells, although prokaryotic promoters and promoters functional in other eukaryotic cells may be used. The promoter is typically derived from promoter sequences of viral or eukaryotic genes. For example, it may be a promoter derived from the genome of a cell in which expression is to occur. With respect to eukaryotic promoters, they may be promoters that function in a ubiquitous manner (such as promoters of α -actin, β -actin, tubulin) or, alternatively, a tissue-specific manner (such as promoters of the genes for pyruvate kinase). Tissue-specific promoters specific for certain cells may also be used. They may also be promoters that respond to specific stimuli, for example promoters that bind steroid hormone receptors. Viral promoters may also be used, for example the Moloney murine leukaemia virus long terminal repeat (MMLV

LTR) promoter, the rous sarcoma virus (RSV) LTR promoter or the human cytomegalovirus (CMV) IE promoter.

5 It may also be advantageous for the promoters to be inducible so that the levels of expression of the heterologous gene can be regulated during the life-time of the cell. Inducible means that the levels of expression obtained using the promoter can be regulated.

10 In addition, any of these promoters may be modified by the addition of further regulatory sequences, for example enhancer sequences. Chimeric promoters may also be used comprising sequence elements from two or more different promoters described above.

Host cells

15

Vectors and polynucleotides of the invention may be introduced into host cells for the purpose of replicating the vectors/polynucleotides and/or expressing the proteins of the invention encoded by the polynucleotides of the invention. Although the proteins of the invention may be produced using prokaryotic cells as host cells, it is preferred
20 to use eukaryotic cells, for example yeast, insect or mammalian cells, in particular mammalian cells.

Vectors/polynucleotides of the invention may introduced into suitable host cells using a variety of techniques known in the art, such as transfection, transformation and
25 electroporation. Where vectors/polynucleotides of the invention are to be administered to animals, several techniques are known in the art, for example infection with recombinant viral vectors such as retroviruses, herpes simplex viruses and adenoviruses, direct injection of nucleic acids and biolistic transformation.

Protein Expression and Purification

Host cells comprising polynucleotides of the invention may be used to express
5 proteins of the invention. Host cells may be cultured under suitable conditions which
allow expression of the proteins of the invention. Expression of the proteins of the
invention may be constitutive such that they are continually produced, or inducible,
requiring a stimulus to initiate expression. In the case of inducible expression, protein
production can be initiated when required by, for example, addition of an inducer
10 substance to the culture medium, for example dexamethasone or IPTG.

Proteins of the invention can be extracted from host cells by a variety of techniques
known in the art, including enzymatic, chemical and/or osmotic lysis and physical
disruption.

15

Administration

Proteins of the invention may preferably be combined with various components to
produce compositions of the invention. Preferably the compositions are combined
20 with a pharmaceutically acceptable carrier, diluent or excipient to produce a
pharmaceutical composition (which may be for human or animal use). Suitable
carriers and diluents include isotonic saline solutions, for example phosphate-buffered
saline. Details of excipients may be found in The Handbook of Pharmaceutical
Excipients, 2nd Edn, Eds Wade & Weller, American Pharmaceutical Association. The
25 composition of the invention may be administered by direct injection. The
composition may be formulated for parenteral, intramuscular, intravenous,
subcutaneous, intraocular, oral or transdermal administration. Typically, each protein
may be administered at a dose of from in the range of 0.5 to 500 ng/kg, preferably in
the range of 1 to 50 ng/kg, more preferably in the range of 5 to 15 ng/kg.

30

In an alternative aspect the present invention provides a pharmaceutical composition
comprising a conjugate, wherein the conjugate is present in an amount such that the
conjugate or a metabolite thereof is provided to the blood plasma of the subject to be
treated in an amount of no greater than about 35,000 ng/day, preferably about 3,500

ng/day, more preferably about 1,000ng/day.

The above dosage relate to a dosage for a 70kg subject. A person skilled in the art would readily be able to modify the recited dosage for a subject having as mass other
5 than 70kg.

The dosage per day is calculated by dividing the dose to be administered to the subject by the anticipated dosage period in days. The anticipated dosage period will typically be the period until the next administration, the period over which the dose is to have
10 effect or the period over which the dose is required to have effect.

The composition may be formulated such that administration daily, weekly or monthly will provide the desired daily dosage. It will be appreciated that the composition may be conveniently formulated for administrated less frequently, such
15 as every 2, 4, 6, 8, 10 or 12 hours.

Polynucleotides/vectors encoding polypeptide components may be administered directly as a naked nucleic acid construct, preferably further comprising flanking sequences homologous to the host cell genome.
20

Uptake of naked nucleic acid constructs by mammalian cells is enhanced by several known transfection techniques for example those including the use of transfection agents. Example of these agents include cationic agents (for example calcium phosphate and DEAE-dextran) and lipofectants (for example lipofectamTM and
25 transfectamTM). Typically, nucleic acid constructs are mixed with the transfection agent to produce a composition.

Preferably the polynucleotide or vector of the invention is combined with a pharmaceutically acceptable carrier or diluent to produce a pharmaceutical
30 composition. Suitable carriers and diluents include isotonic saline solutions, for example phosphate-buffered saline. The composition may be formulated for parenteral, intramuscular, intravenous, subcutaneous, intraocular or transdermal administration.

The routes of administration and dosage regimens described are intended only as a guide since a skilled practitioner will be able to determine readily the optimum route of administration and dosage regimens for any particular patient and condition.

5 Viral vectors

In a preferred embodiment the conjugate is administered using a viral vector, more preferably a retroviral vector.

10 Retroviruses

The retroviral vector for use the present invention may be derived from or may be derivable from any suitable retrovirus. A large number of different retroviruses have been identified. Examples include: murine leukemia virus (MLV), human
15 immunodeficiency virus (HIV), simian immunodeficiency virus, human T-cell leukemia virus (HTLV). equine infectious anaemia virus (EIAV), mouse mammary tumor virus (MMTV), Rous sarcoma virus (RSV), Fujinami sarcoma virus (FuSV), Moloney murine leukemia virus (Mo-MLV), FBR murine osteosarcoma virus (FBR MSV), Moloney murine sarcoma virus (Mo-MSV), Abelson murine leukemia virus
20 (A-MLV), Avian myelocytomatosis virus-29 (MC29), and Avian erythroblastosis virus (AEV). A detailed list of retroviruses may be found in Coffin *et al.*, 1997, "retroviruses", Cold Spring Harbour Laboratory Press Eds: JM Coffin, SM Hughes, HE Varmus pp 758-763.

25 Details on the genomic structure of some retroviruses may be found in the art. By way of example, details on HIV and Mo-MLV may be found from the NCBI Genbank (Genome Accession Nos. AF033819 and AF033811, respectively).

Retroviruses may be broadly divided into two categories: namely, "simple" and
30 "complex". Retroviruses may even be further divided into seven groups. Five of these groups represent retroviruses with oncogenic potential. The remaining two groups are the lentiviruses and the spumaviruses. A review of these retroviruses is presented in Coffin *et al.*, 1997 (*ibid*).

The lentivirus group can be split even further into "primate" and "on-primate". Examples of primate lentiviruses include human immunodeficiency virus (HIV), the causative agent of human auto-immunodeficiency syndrome (AIDS), and simian immunodeficiency virus (SIV). The non-primate lentiviral group includes the
5 prototype "slow virus" visna/maedi virus (VMV), as well as the related caprine arthritis-encephalitis virus (CAEV), equine infectious anaemia virus (EIAV) and the more recently described feline immunodeficiency virus (FIV) and bovine immunodeficiency virus (BIV).

10 This invention also relates to the use of vectors for the delivery of a conjugate in the form of a nucleotide sequence to a haematopoietic stem cell (HSC).

Gene transfer involves the delivery to target cells, such as HSCs, of an expression cassette made up of one or more nucleotide sequences and the sequences controlling
15 their expression. This can be carried out *ex vivo* in a procedure in which the cassette is transferred to cells in the laboratory and the modified cells are then administered to a recipient. Alternatively, gene transfer can be carried out *in vivo* in a procedure in which the expression cassette is transferred directly to cells within an individual. In both strategies, the transfer process is usually aided by a vector that helps deliver the
20 cassette to the appropriate intracellular site.

Bone marrow has been the traditional source of HSCs for transduction, more recent studies have suggested that peripheral blood stem cells or cord blood cells may be equally good or better target cells (Cassel *et al* 1993 *Exp Hematol* 21: 585-591;
25 Bregni *et al* 1992 *Blood* 80: 1418-1422; Lu *et al* 1993 *J Exp Med* 178: 2089-2096).

Further anticancer agents

The conjugate of the present invention may be used in combination with one or more
30 other active agents, such as one or more cytotoxic drugs. Thus, in one aspect of the present invention the method further comprises administering another active pharmaceutical ingredient, such as a cytotoxic drug, either in combined dosage form with the conjugate or in a separate dosage form. Such separate cytotoxic drug dosage form may include solid oral, oral solution, syrup, elixir, injectable, transdermal,

transmucosal, or other dosage form. The conjugate and the other active pharmaceutical ingredient can be combined in one dosage form or supplied in separate dosage forms that are usable together or sequentially.

- 5 Examples of cytotoxic drugs which may be used in the present invention include: the alkylating drugs, such as cyclophosphamide, ifosfamide, chlorambucil, melphalan, busulfan, lomustine, carmustine, chlormethine (mustine), estramustine, treosulfan, thiotepa, mitobronitol; cytotoxic antibiotics, such as doxorubicin, epirubicin, aclarubicin, idarubicin, daunorubicin, mitoxantrone (mitozantrone), bleomycin, dactinomycin and
10 mitomycin; antimetabolites, such as methotrexate, capecitabine, cytarabine, fludarabine, cladribine, gemcitabine, fluorouracil, raltitrexed, mercaptopurine, tegafur and tioguanine; vinca alkaloids, such as vinblastine, vincristine, vindesine and vinorelbine, and etoposide; other neoplastic drugs, such as amsacrine, altretamine, crisantaspase, dacarbazine and temozolomide, hydroxycarbamide (hydroxyurea), pentostatin, platinum
15 compounds including: carboplatin, cisplatin and oxaliplatin, porfimer sodium, procarbazine, razoxane, taxanes including: docetaxel and paclitaxel, topoisomerase I inhibitors including: irinotecan and topotecan, trastuzumab, and tretinoin.

In a preferred embodiment the further cytotoxic drug is doxorubicin, melphalan or
20 cisplatin.

The conjugate of the present invention can also be used to use the permeability of tumor cells and vessels to compounds for diagnostic purposes. For instance, the conjugate can be used to increase the tumor uptake of radiolabelled antibodies or hormones (tumor-
25 imaging compounds) in radioimmunosciintigraphy or radiotherapy of tumors.

Figures and Examples

The present invention will further be described by reference to the following non-
30 limiting Examples and Figures in which:

Fig. 1 Effect of mTNF and NGR-mTNF on tumor growth and body weight of animals bearing RMA-T lymphomas.

Animals bearing RMA-T tumors (5 mice/group) were treated i.p. with NGR-mTNF or mTNF at day 12 after tumor implantation (A) or at day 10, 11 and 12 (B), in two separate experiments (Exp. 1 and Exp. 2). Tumor volumes in Exp. 1 (A) and Exp. 2 (B) and animal body weight in Exp. 1 (C) 1-4 days after treatment are shown. The
5 arrowheads in panel C indicate the time of treatment.

Fig. 2 Circulating levels of sTNF-R2 and their role in regulating the activity of NGR-mTNF and NGR-hTNF.

Panel A: serum levels of sTNF-R1 and sTNF-R2 in B16F1 tumor bearing mice 1 hour
10 after treatment with various doses of NGR-mTNF or mTNF. Animals (3 mice/group) were treated at day 6.

Panel B: effect of the anti-sTNF-R2 mAb 6G1 on the anti-tumor activity of NGR-mTNF. MAb 6G1 (100 µg) was administered to animals bearing B16F1 tumors at day 5 and 8. One hour later each animal was treated with NGR-mTNF at the
15 indicated doses, and 2 hours later with melphalan (90 µg, 5 mice/group).

Panel C: effect NGR-hTNF and hTNF on the growth of RMA-T tumors. Mice were treated with various doses of each cytokine at day 11. N.S.: not significant (*t*-test).

Fig. 3 Effect of melphalan, alone (A) or in combination with NGR-mTNF (C) or mTNF (D), on the tumor growth (A-D) and body weight (E-F) of mice bearing B16F1 melanoma.

The animals were treated (i.p.) with the drugs and the doses indicated in each panel (5 animals/group) at day 4, 7 and 9 after tumor implantation (indicated by arrows).

25

Fig. 4 Effect of various doses of doxorubicin, alone (white bars) or in combination with NGR-mTNF (black bars) on the tumor growth (A, B) body weight (C, D) and survival (E) of mice bearing B16F1 melanomas.

The drugs were administered to the animals (5 mice/group i.p.) 5 days after tumor
30 implantation.

Fig. 5 Role of TNF receptors in the synergistic activity of NGR-mTNF and melphalan.

- Panel A: effect of mAb V1q (an anti-mTNF neutralizing antibody) on the anti-tumor activity of melphalan in combination with NGR-mTNF in the B16F1 model. The drugs were administered at day 5. Mab V1q and NGR-TNF were pre-mixed and incubated for 1 hour before injection into animals.
- 5 Panel B: effect of melphalan in combination with NGR-hTNF at the indicated doses.

Fig. 6 Effect of NGR-mTNF on the penetration of doxorubicin in B16F1 and RMA-T tumors.

- Panel A: bright field (upper panels) and fluorescence (lower panels) microscopy of
10 B16F1 cells incubated *in vitro* with 100 µg/ml doxorubicin (30 min, 37°C). Inset: merge of bright field and fluorescence images.
- Panel B: stability of the B16F1 fluorescence signal after *in vitro* treatment with doxorubicin. B16F1 cells were incubated with various doses of doxorubicin in culture medium (30 min, 37°C), washed with 0.9% sodium chloride, and fixed with
15 4% formaldehyde. The cells were then incubated for 0 hours or 24 hours in culture medium at 4°C, washed again and analyzed by FACS.
- Panel C, F: representative FACS analysis of cells recovered from B16F1 (C) or RMA-T (F) tumors 2 hours after *in vitro* administration of doxorubicin alone (320 µg) or in combination with NGR-mTNF (0.1 ng). Dashed lines indicate the fluorescence
20 interval considered positive.
- Panel D, G: mean \pm SE fluorescence of B16F1 (D) or RMA-T (G) cells recovered from tumors.
- Panel E, H: mean \pm SE of positive cells recovered from B16F1 (E) RMA-T (H) tumors.
- 25 Statistical analysis by two-tailed *t*-test, $P < 0.05$ (*).

- Fig. 7 Schematic representation of the hypothetical interactions of low (A), moderate (B) and high (C) doses of NGR-TNF with soluble and membrane receptors in normal vessels (CD13-negative) and in tumor associated vessels
30 (CD13-positive).**

Black arrows indicate TNF receptor signalling or extracellular domain shedding.

Fig. 8 Effect of RGD-TNF on the tumor growth (Fig. 8A) and body weight (Fig. 8B) of an animal bearing RMA-T.

5 Fig. 9 Effect of a single treatment (arrow) with IFN γ -NGR on the growth of RMA lymphoma tumors in C57B6 mice (Fig. 9A & Fig. 9C) and on animal weight (Fig. 9B).

Fig. 10 Effect of NGR-TNF and cisplatinum on RMA tumors in C57/BL6 mice.

10 Example 1 - Tumor cell lines and reagents.

Mouse B16F1 melanoma and RMA-T lymphoma cells were cultured as described previously (14, 15). MAb 6G1 (rat anti-p75 mTNF receptor antagonist) was produced and characterized as described previously (16, 17). MAb V1q (rat anti-mTNF) was
15 kindly supplied by Dr. D. Mannel (University of Regensburg, Germany). Melphalan (Alkeran) was obtained from Glaxo-Wellcome (London, Great Britain). Doxorubicin (Adriablastina) was purchased from Pharmacia-Upjohn (Milan, Italy).

Example 2 - Preparation of human and murine TNF and NGR-TNF.

20

Human and murine TNF and NGR-TNF (consisting of TNF fused with the C-terminus of CNGRCG) were prepared by recombinant DNA technology and purified from *E.coli* cell extracts, as described (14). All solutions used in the chromatographic steps were prepared with sterile and endotoxin-free water (Salf, Bergamo, Italy).
25 Protein concentration was measured with a commercial protein quantification assay kit (Pierce, Rockford, IL). The *in vitro* cytolytic activity of human TNF (hTNF), estimated from a standard cytolytic assay with L-M mouse fibroblasts (18), was 5.4×10^7 Units/mg, whereas that of purified NGR-hTNF was 1.4×10^8 Units/mg. The cytolytic activity of murine TNF (mTNF), was 7.6×10^7 Units/mg, whereas that of
30 NGR-mTNF was 9.1×10^7 Units/mg. The hydrodynamic volumes of NGR-mTNF, NGR-hTNF and mTNF were similar to those of hTNF, a homotrimeric protein (19), by gel filtration chromatography on a Superdex 75 HR column (Pharmacia, Sweden). Electrospray mass spectrometry of each product determined the following molecular masses: NGR-hTNF, 17937.6 ± 1.9 Da (expected for CNGRCG-hTNF₁₋₁₅₇ monomers, 17939.4 Da); hTNF, 17349 ± 1.3 (expected for hTNF₁₋₁₅₇, 17350.7); NGR-mTNF,
35 17841.16 ± 2.5 (expected for CNGRCG-mTNF₁₋₁₅₆, 17844.2), mTNF, 17384.9 ± 2

(expected for Met-mTNF₁₋₁₅₆, 17386.7). The endotoxin content of each product, measured using the quantitative chromogenic limulus amoebocyte lysate (LAL) test (BioWhittaker), was: NGR-hTNF, 0.079 Units/μg; hTNF, 0.117 Units/μg; NGR-mTNF, 0.082 Units/μg; mTNF, 1.61 Units/μg.

5

Example 3 - *In vivo* studies.

Studies on animal models were approved by the Ethical Committee of the San Raffaele H Scientific Institute and performed according to the prescribed guidelines.

10 C57BL/6 mice (Charles River Laboratories, Calco, Italy) weighing 16-18 g were challenged with subcutaneous injection in the left flank of 5×10^4 RMA-T or B16F1 living cells; 4-12 days later, the mice were treated with TNF or NGR-TNF solutions (100 μl) followed 2 hours later by administration of melphalan or doxorubicin solution (100 μl). Unless specified, all drugs were administered intraperitoneally

15 (i.p.). All drugs were diluted with 0.9% sodium chloride, containing 100 μg/ml endotoxin-free human serum albumin (Farma-Biagini, Lucca, Italy), except for doxorubicin, which was diluted with 0.9% sodium chloride alone. Tumor growth was monitored daily by measuring the tumors with calipers as previously described (20). Animals were sacrificed before the tumors reached 1.0-1.5 cm in diameter. Tumor

20 sizes are shown as mean \pm SE (5 animals/group).

Example 4 - Soluble TNF receptor assays.

Soluble p55-TNF receptor (sTNF-R1) and soluble p75-TNF receptor (sTNF-R2) in

25 animal sera were measured using the Quantikine M kit (R & D Systems, Minneapolis, MN 55413).

Example 5 - Detection of doxorubicin in tumors.

30 C57/BL6 mice bearing B16F1 or RMA-T tumors (diameter, 0.5-1 cm) were treated with or without NGR-m TNF (0.1 ng, i.p.), followed 2 hours later by doxorubicin (320 μg, i.p.). After 2 hours the animals were sacrificed and the tumors were excised. Each tumor was weighed, disaggregated, resuspended in cold phosphate-buffered

saline (PBS) and filtered through 70 μ m filters. The cells were resuspended with cold PBS (50 ml), centrifuged (1500 rpm, 10 min, 4°C), resuspended in cold PBS (2.5 ml/g of tumor tissue) and mixed with freshly prepared PBS containing 8% formaldehyde (2.5 ml/g of tissue). The cells were stored in the dark at 4°C overnight, and then
5 analyzed by FACS. The FACScan (Becton-Dickinson) was calibrated with cells recovered from untreated tumors. Each sample was then analyzed using the FL-3 filter and Cell Quest software.

**Example 6 -Dose-response curves of NGR-mTNF and mTNF in murine
10 lymphoma and melanoma models.**

The anti-tumor activity of NGR-mTNF and mTNF was first characterized in the absence of chemotherapeutic drugs. To compare the dose-response curves of NGR-mTNF and mTNF we performed several experiments based on single or repeated
15 administration (i.p.) of various doses of NGR-mTNF and mTNF (from 0.01 to 10000 ng) to RMA-T lymphoma- or B16F1 melanoma-bearing mice. Murine TNF delayed tumor growth when administered at high doses (10000 ng) (Fig. 1A); no effects were induced by doses lower than 100 ng, either with single (Fig. 1A) or repeated administrations (Fig. 1B). NGR-mTNF was markedly more potent. In this case we
20 observed anti-tumor effects even with doses as low as 0.01 ng (Fig. 1A, B). However, the dose-response curve was more complex. For instance, the effect of 10 ng was surprisingly lower than that of 0.01-0.1 ng and 1000-10000 ng. A bell-shaped dose-response curve was observed in several other experiments conducted in the RMA-T model as well as in the B16F1 melanoma model (not shown). These results suggest
25 that 1) the efficacy of low doses of NGR-mTNF is markedly higher than that of mTNF, and 2) doses of NGR-mTNF greater than 1-10 ng activate negative feed-back mechanisms that inhibit its potential anti-tumor activity.

**Example 7 - Nanogram doses of NGR-TNF, but not picograms, induce soluble
30 TNF receptor shedding.**

The protective mechanisms responsible for the bell-shaped dose-response curve of NGR-mTNF were then investigated. Since exogenously administered TNF can

induce soluble TNF receptor (sTNF-Rs) shedding *in vivo* (21), we hypothesized that the lower efficacy of 10 ng of NGR-TNF was related to induction of sTNF-R1 and/or sTNF-R2 and, consequently, to neutralization of its interaction with membrane receptors.

5

To test this hypothesis, we measured the levels of sTNF-R1 and sTNF-R2 in the serum of tumor bearing mice collected 1 hour after administration of various doses of mTNF and NGR-mTNF. As expected, both products induced sTNF-R2 shedding, but not sTNF-R1 shedding, at doses greater than 4 ng (Fig. 2A).

10

To assess whether sTNF-R2 shedding regulates the activity of NGR-mTNF, we coadministered this cytokine with mAb 6G1, an antagonist anti-sTNF-R2 antibody that prevents the binding of mTNF to soluble and membrane murine TNF-R2 (16). The anti-tumor activity of 10 ng of NGR-mTNF was potentiated by mAb 6G1 (Fig. 2B), in line with the hypothesis that sTNF-R2 plays a role in inhibiting the anti-tumor effects of NGR-mTNF.

15

To further support this hypothesis we compared the *in vivo* dose-response curve of NGR-mTNF with that of NGR-hTNF, taking advantage of the fact that the human cytokine cannot bind murine sTNF-R2 (22). We found that the dose-response curve of NGR-hTNF was not bell-shaped and that 10 ng of NGR-hTNF is as active as 1 ng (Fig. 2C). It is also remarkable that 1 ng was sufficient to induce the maximum anti-tumor effect. This may suggest that receptor binding on vessels can be achieved with very low blood levels of NGR-hTNF.

20

Taken together, the results of these experiments strongly suggest that NGR-mTNF and mTNF, at doses greater than 4 ng, induce shedding of sTNF-R2 in amounts sufficient to inhibit their anti-tumor activity.

25
30 **Example 8 - Picogram doses of NGR-mTNF are sufficient to enhance the therapeutic effect of melphalan and doxorubicin.**

We then investigated whether targeted delivery of low doses of NGR-mTNF to tumor vessels could enhance the anti-tumor activity of chemotherapeutic drugs. These

experiments were conducted in the B16F1 model, a spontaneous mouse melanoma characterized by scarce immunogenicity and low sensitivity to melphalan. Melphalan (90 µg) was unable to effect the growth of tumors when injected alone (Fig. 3A). Similarly, mTNF (0.1 ng alone, i.p.) was virtually inactive, while the same dose of NGR-mTNF modestly delayed the tumor growth (Fig. 3B, upper panels). The combination of melphalan with 0.1 ng of NGR-mTNF induced stronger anti-tumor effects than the single agents, indicating a synergistic effect (Fig. 3C). Remarkably, the combination of melphalan with 0.1 ng of NGR-mTNF was more effective than the combination with 5000 ng of mTNF (Fig. 3C-D). We observed this synergism even when NGR-mTNF (0.1 ng) was injected i.v. (not shown).

Two similar experiments were conducted with doxorubicin in the B16F1 model. Animals were treated five days after tumor implantation, with or without NGR-mTNF and, 2 hours later, with various doses of doxorubicin (20-320 µg, i.p.). In both experiments, the effect of doxorubicin plus NGR-mTNF was stronger than that of doxorubicin alone (Fig. 4A, B, E), indicating that NGR-mTNF markedly improves the efficacy of this drug. For example, the effect of doxorubicin (40 µg) plus NGR-mTNF (0.1 ng) was stronger than that of 320 µg of doxorubicin alone (Fig. 4B), while, the effect of doxorubicin (20 µg) plus NGR-mTNF was lower (Fig. 4A). From these results we estimate that the activity of doxorubicin is potentiated 8-10 fold by NGR-mTNF.

In conclusion, these results suggest that picogram doses of NGR-TNF are sufficient to improve the response of tumors to both melphalan and doxorubicin.

Example 9 - Low doses of NGR-mTNF are not toxic and do not increase the toxicity of melphalan.

To estimate the efficacy/toxicity ratio of each treatment, we monitored the animal body weight daily and animal survival after treatment. While therapeutic doses of mTNF (10000 ng) induced marked loss of body weight in RMA-T bearing animals (Fig. 1C, left), therapeutic doses of NGR-mTNF (0.01-1 ng) did not cause loss of body weight (Fig. 1C, right). Moreover, neither NGR-mTNF nor mTNF (1 ng each)

increased the lethality of 200 µg of melphalan in mice bearing the RNA-T tumor (Table 1).

**Table 1. Effect of mTNF and NGR-mTNF on the toxicity of
5 Melphalan (high dose) in tumor-bearing mice^a**

Treatment	No. of mice alive
	3 days after treatment
None	5/5 (100%)
Melphalan	7/10 (70%)
Melphalan + mTNF	8/10 (80%)
15 Melphalan + NGR-mTNF	8/10 (80%)

^aC57BL6 mice, bearing 11-day old tumors, were treated (i.p.) with 1 ng of NGR-mTNF or mTNF and, 2 hours later, with 200 µg of melphalan.

20

In the B16F1 model, therapeutic doses of NGR-mTNF (0.1 ng) did not cause loss of body weight, even when combined with melphalan (Fig. 3E). In contrast, melphalan combined with therapeutic doses of mTNF (5 µg) induced marked loss of body weight (Fig. 3F). In addition, NGR-mTNF (0.1 ng) did not increase the loss of body
25 weight caused by high doses of doxorubicin (Fig. 4C-D).

These results suggest that picogram doses of NGR-mTNF increase the response of tumors to melphalan and doxorubicin with no evidence of increased toxicity.

30 **Example 10 - TNF-R1 activation is necessary and sufficient for the synergism between NGR-TNF and chemotherapeutic drugs.**

The mechanisms of the synergism between low doses of NGR-mTNF and chemotherapy were then investigated.

To assess whether these mechanisms rely on TNF-Rs activation we tested the effect of mAbV1q, a neutralizing anti-mTNF antibody, on the anti-tumor activity of NGR-mTNF (0.1 ng) in combination with melphalan (90 μ g). MAb V1q inhibited, at least partially, the anti-tumor activity of these drugs in the B16F1 model (Fig. 5A). This suggests that the interaction between the TNF moiety and TNF-Rs is critical for the activity of the conjugate.

10

The role of TNF-R1 and TNF-R2 was then studied. To this end, we evaluated the effect of melphalan in combination with 0.01 ng or 0.1 ng of NGR-hTNF, a TNF-R1 specific agonist (22). The effect of melphalan in the B16F1 model was potentiated by NGR-hTNF (Fig. 5B) suggesting that TNF-R1 activation is sufficient for the synergism.

15

Example 11 - The synergy between NGR-TNF and chemotherapy is not dependent on tumor cell cytotoxicity.

To assess whether the synergism depends directly on cytotoxicity against tumor cells we measured the effect of each compound, alone or in combination, on cultured B16F1 cells. Neither melphalan or NGR-mTNF, alone or in combination, killed these cells in a 48 hour *in vitro* assay (not shown). Similarly, NGR-mTNF did not enhance the cytotoxic activity of doxorubicin *in vitro* (not shown). These results suggest that the synergism observed *in vivo* is not directly dependent on cytotoxic effects against tumor cells and points to an indirect role of a component of the tumor stroma, e.g. the endothelial lining of tumor vessels.

25

Example 12 - NGR-TNF increases the penetration of doxorubicin in murine melanomas and lymphomas.

30

We then investigated whether NGR-mTNF could increase the penetration of chemotherapeutic drugs in tumors. To this aim we measured the amount of

doxorubicin that had penetrated B16F1 and RMA-T tumors, 2 hours after administration, taking advantage from the fluorescent properties of this drug (23). Preliminary experiments showed that the nuclei of B16F1 cells become fluorescent after these cells are exposed to doxorubicin *in vitro* (Fig. 6A). The fluorescence signal is dose-dependent and stable for at least 24 hours, when the cells are fixed with formaldehyde and kept at 4°C, as measured by FACS (Fig. 6B). Thus, the fluorescence intensity of tumor cells recovered from animals after treatment is an indication of the amount of doxorubicin that has penetrated tumors. We observed that 0.1 ng of NGR-mTNF, administered 2 hours before doxorubicin, increased the fluorescence intensity and the percentage of positive cells recovered from both B16F1 and RMA-T tumors, 2 hours after treatment (2-5-fold, Fig. 6C-H). This suggests that NGR-mTNF increased the number of cells that were reached by doxorubicin as well as the intracellular amount of drug.

15 **Example 13 – Effect of RGD-TNF on tumors**

C57/BL6 mice bearing RMA-T tumors (5 mice/group) were treated intraperitoneally with melphalan alone, or in combination with RGD-TNF or NGR-TNF. The effect on tumor volume is shown in Fig. 8A and the effect on animal weight is shown in Fig. 8B. These results demonstrate that RGD-TNF is also active in the picogram range.

Example 14 – Effect of IFN γ -NGR on tumors

C57/BL6 mice bearing RMA lymphoma tumors were treated with or without IFN γ (3ng) or IFN γ -NGR (3ng). After 21 days the animals were sacrificed. The results of tumor volume and of animal weight loss can be seen in Figs. 9A and 9B. In addition, C57/BL6 mice bearing RMA lymphoma tumors were treated with or without IFN γ (3ng), IFN γ -NGR (3ng), IFN γ -NGR (3ng) plus anti-CD13 R3-63 mAb (25 μ g) or IFN γ -NGR (3ng) plus mAB 19E12 (50 μ g). The mAB 19E12 is an irrelevant IgG used as a negative control in the experiment. The results demonstrate that IFN γ -NGR is active in the picogram range.

Example 15 – Picogram doses of NGR-TNF are sufficient to enhance the therapeutic effect of cisplatin

We investigated whether targeted delivery of low doses of NGR-TNF to tumor vessels could enhance the anti-tumor activity of the anti-cancer drug, cisplatin. These experiments were carried out in C57/BL6/N mice bearing RMA-T tumors of initial age 8 weeks. The mice were treated with or without cisplatin or NGR-mTNF with treatment at day 10. The results are shown in Fig. 10. In this figure, Cys = Cisplatin Teva solution 0.5 mg/ml; NGR = NGR-mTNF. The diluent was HAS 100mg/ml in NaCl 0.9%. The results suggest that picogram doses of NGR-TNF are sufficient to enhance the therapeutic effect of cisplatin.

Summary of Advantages

Alteration of vascular permeability and interstitial pressure, endothelial cell damage and fibrin deposition are important mechanisms for the anti-tumor activity of TNF, either alone or in combination with chemotherapeutic drugs. After, infusion in animals or patients TNF can also induce negative feedback mechanisms that neutralize most of these effects. For example, TNF, even at moderate doses, can induce the release of soluble p55 and p75 TNF receptors that may prevent its interaction with membrane receptors (21, 24). Although these soluble inhibitors may protect the body from the harmful effects of this cytokine, they may also prevent its anti-tumor activity and could explain, in part, the need of high doses of TNF for effective therapy. In this work we postulated that homing low doses of TNF to tumor vessels represents a new strategy to avoid toxic reactions as well as negative feedback mechanisms, while preserving its synergism with chemotherapy. To verify this hypothesis, we have investigated the anti-tumor activity of high and low doses of NGR-mTNF and mTNF, ranging from picogram to microgram quantities, in two murine models based on subcutaneous RMA-T lymphoma and B16F1 melanoma tumors. The study was carried out using these cytokines alone or in combination with melphalan or doxorubicin. While mTNF was virtually inactive in these models at lower doses than 100-1000 ng, we found that NGR-mTNF, even alone, could induce anti-tumor effects with doses as low as 0.01-0.1 ng. Since the LD₅₀ values of mTNF and NGR-mTNF are similar and correspond to about 50,000 ng in RMA-T tumor-

bearing mice (14), these results indicate that the efficacy/toxicity ratio of NGR-mTNF is 10^4 - 10^5 times greater than that of mTNF.

Administration of minute amounts of NGR-mTNF (0.1 ng) to tumor-bearing animals
5 potentiated the anti-tumor activity of melphalan and doxorubicin with no evidence of
increased toxicity, as judged by tumor mass reduction, animal survival and weight
loss after treatment. This suggests that NGR-mTNF improves the therapeutic index of
these drugs. It is noteworthy that 5×10^4 -fold greater doses of mTNF were necessary
to enhance the effect of melphalan to comparable levels, causing marked loss of body
10 weight.

The fact that both melphalan and doxorubicin at doses virtually inactive in the B16F1
model reduced tumor growth when combined with NGR-mTNF indicates that these
drugs act synergistically. Studies on the mechanism of action showed that the
15 synergism relies on the interaction of NGR-mTNF with TNF-R1 on stromal cells,
most likely endothelial cells, and much less on tumor cells. In addition, we found that
vascular targeting with NGR-mTNF improves cytotoxic drug penetration in tumors.
Noteworthy, NGR-mTNF increased both the percentage of cancer cells that can be
reached by doxorubicin in 2 hours as well as the intracellular amount of drug,
20 suggesting that NGR-TNF can alter drug-penetration barriers. Previous studies
showed that TNF can rapidly increase endothelial permeability (25, 26), and can
decrease interstitial fluid pressure (8) that are believed to be important barriers for
drug penetration in tumors (1). Possibly, these mechanisms increase convective
transport of drugs through the tumor vessel wall and interstitium, finally resulting in
25 increased drug uptake by tumor cells. The timing of administration is likely critical
for these mechanisms, as TNF can also induce intravascular coagulation (27) leading
to vessel occlusion and reduction of tumor perfusion. According to this view, we
observed that the effect of melphalan was higher when this drug was administered 2
hours after NGR-TNF than after 6 hours (data not shown).

30

The hypothesis that vascular targeting could avoid negative feedback mechanisms,
usually associated with TNF therapy, is supported by the observation that picogram
doses of NGR-mTNF do not induce soluble receptor shedding, while both NGR-
mTNF and mTNF rapidly induce the release of sTNF-R2 into the circulation at doses

greater than 4-10 ng. These levels of sTNF-R2 inhibited most of the anti-tumor activity of 10 ng of NGR-mTNF and may explain the paradoxical observation that 10 ng is less active than 0.1 ng. Likely, a large proportion of injected molecules were rapidly complexed by sTNF-Rs and their activity was blocked.

5

The molecular mechanisms underlying the selective interaction of low doses of NGR-mTNF with tumor blood vessels has been partially elucidated. We have shown recently that different CD13 isoforms are expressed in tumor-associated vessels, in epithelia and in myeloid cells, and that the NGR domain of NGR-TNF selectively
10 recognizes a CD13 isoform associated with tumor vessels (28). We hypothesize, therefore, that low blood levels of NGR-mTNF can rapidly interact with CD13-positive endothelial cells because of high-avidity multivalent binding involving both CD13 and TNF-Rs, and little or not at all with CD13-negative endothelial cells of normal vessels, because of lower avidity. A schematic representation of these
15 concepts and of the hypothetical interactions of NGR-TNF with soluble and membrane receptors is shown in Fig. 7.

We have also found that RGD-TNF and IFN γ -NGR are active in the picogram range. We have also shown that NGR-TNF increases the effect of cisplatinum.

20

In conclusion, we have found that targeted delivery of picogram doses of cytokines to tumor vessels enhances the anti-tumor activity of chemotherapeutic drugs in mice without inducing soluble receptor shedding. Given that the CNGRC motif is expected to target murine as well as human tumor associated vessels (29), our results suggest
25 that the combination of low doses of targeted cytokines with anti-cancer drugs could increase their therapeutic index in human patients.

All publications mentioned in the above specification are herein incorporated by reference. Various modifications and variations of the described methods and system
30 of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments.

Indeed, various modifications of the described modes for carrying out the invention which are apparent to those skilled in molecular biology or related fields are intended to be within the scope of the following claims.

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Claims

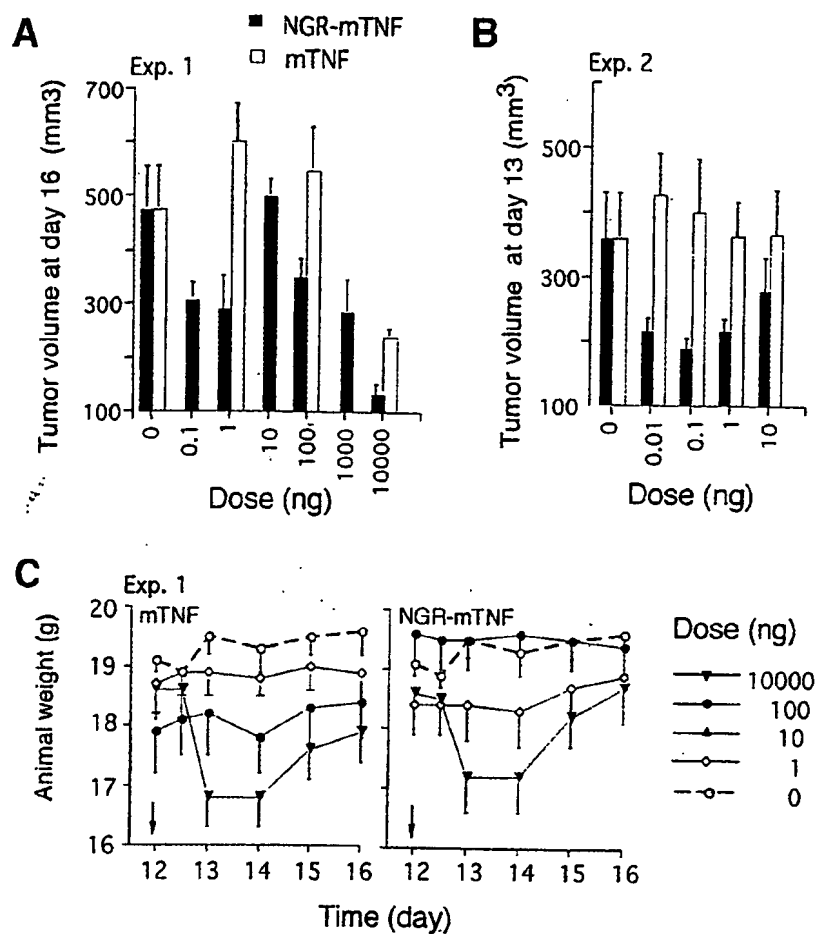
1. A pharmaceutical composition comprising a conjugate of a cytokine and a tumor
5 targeting moiety (TTM) and a pharmaceutically acceptable carrier, diluent or
excipient, wherein the cytokine is present in an amount which does not induce a
negative feedback mechanism.
2. A pharmaceutical composition according to claim 1 wherein the cytokine is
10 present in an amount which does not induce soluble cytokine receptor shedding.
3. A pharmaceutical composition according to claim 1 or 2 wherein the conjugate is
present in an amount to provide a dosage in the range of 0.5 to 500 ng/kg.
- 15 4. A pharmaceutical composition according to claim 3 wherein the conjugate is
present in an amount to provide a dosage in the range of 1 to 50 ng/kg.
5. A pharmaceutical composition according to claim 4 wherein the conjugate is
present in an amount to provide a dosage in the range of 5 to 15 ng/kg.
20
6. A pharmaceutical composition according to claim 1 or 2 wherein the conjugate is
present in an amount such that the conjugate, or a metabolite thereof, is provided
to the blood plasma of a patient to be treated in an amount of no greater than about
35,000 ng/day for a 70kg patient.
- 25 7. A pharmaceutical composition according to any preceding claim wherein the
cytokine is an inflammatory cytokine.
8. A pharmaceutical composition according to any preceding claim wherein the
cytokine is a chemotherapeutic cytokine.
30
9. A pharmaceutical composition according to any preceding claim wherein the
cytokine is $\text{TNF}\alpha$, $\text{TNF}\beta$, $\text{IFN}\alpha$, $\text{IFN}\beta$, $\text{IFN}\gamma$, IL-1, 2, 4, 6, 12, 15, EMAP II,
vascular endothelial growth factor (VEGF), PDGF, PD-ECGF or a chemokine.

10. A pharmaceutical composition according to claim 9 wherein the cytokine is TNF- α , TNF- β or IFN- γ .
- 5 11. A pharmaceutical composition according to any preceding claim wherein the TTM is a tumor vasculature targeting moiety (TVTM).
12. A pharmaceutical composition according to claim 11 wherein the TVTM is a binding partner of a tumor vasculature receptor, marker or other extracellular component.
- 10 13. A pharmaceutical composition according to any one of claims 1 to 10 wherein the TTM is a binding partner of a tumor receptor, marker or other extracellular component.
- 15 14. A pharmaceutical composition according to any preceding claim wherein the TTM is an antibody or ligand, or a fragment thereof.
- 20 15. A pharmaceutical composition according to any preceding claim wherein the TTM is contains the NGR or RGD motif, or is HIV-tat, Annexin V, Osteopontin, Fibronectin, Collagen Type I or IV, Hyaluronate, Ephrin, or is a binding partner to oncofetal fibronectin; or a fragment thereof.
- 25 16. A pharmaceutical composition according to claim 15 wherein the TTM contains the NGR motif.
- 30 17. A pharmaceutical composition according to claim 16 wherein the TTM is CNGRCVSGCAGRC, NGRAHA, GN GRG, cycloCVLNGRMEC, linear or cyclic CNGRC.
18. A pharmaceutical composition according to claim 15 wherein the TTM contains the NGR motif.

19. A pharmaceutical composition according to claim 14 wherein the TTM is targeted to VEGFR, ICAM 1, 2 or 3, PECAM-1, CD31, CD13, VCAM-1, Selectin, Act RII, ActRIIB, ActRI, ActRIB, CD44, aminopeptidase A, aminopeptidase N (CD13), $\alpha\text{v}\beta 3$ integrin, $\alpha\text{v}\beta 5$ integrin, FGF-1, 2, 3, or 4, IL-1R, EPHR, MMP, NG2, tenascin, oncofetal fibronectin, PD-ECGFR, TNFR, PDGFR or PSMA.
20. A pharmaceutical composition according to any preceding claim wherein the conjugate is in the form of a fusion protein.
21. A pharmaceutical composition according to any one of claims 1 to 19 wherein the conjugate is in the form of nucleic acid.
22. A pharmaceutical composition according to any preceding claim wherein the composition further comprises another antitumor agent or diagnostic tumor-imaging compound.
23. A pharmaceutical composition according to claim 22 wherein the further antitumor agent is doxorubicin, melphalan or cisplatin.
24. Use of a conjugate as defined in any preceding claim or a pharmaceutical composition according to any preceding claim for the preparation of a medicament for treatment or diagnosis of cancer.
25. A method of treating or diagnosing cancer comprising administering to a patient in need of the same a conjugate as defined in any one of claims 1 to 23 or a pharmaceutical composition according to any one of claims 1 to 23 in an effective amount, wherein said amount does not induce a negative feedback mechanism.

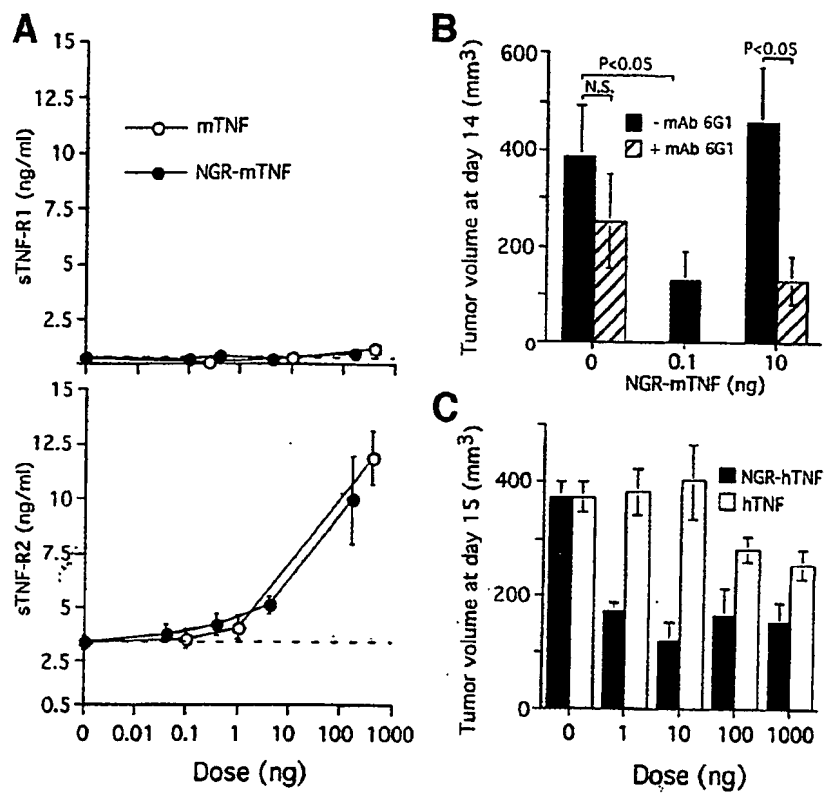
1/10

FIGURE 1



2/10

FIGURE 2



3/10

FIGURE 3

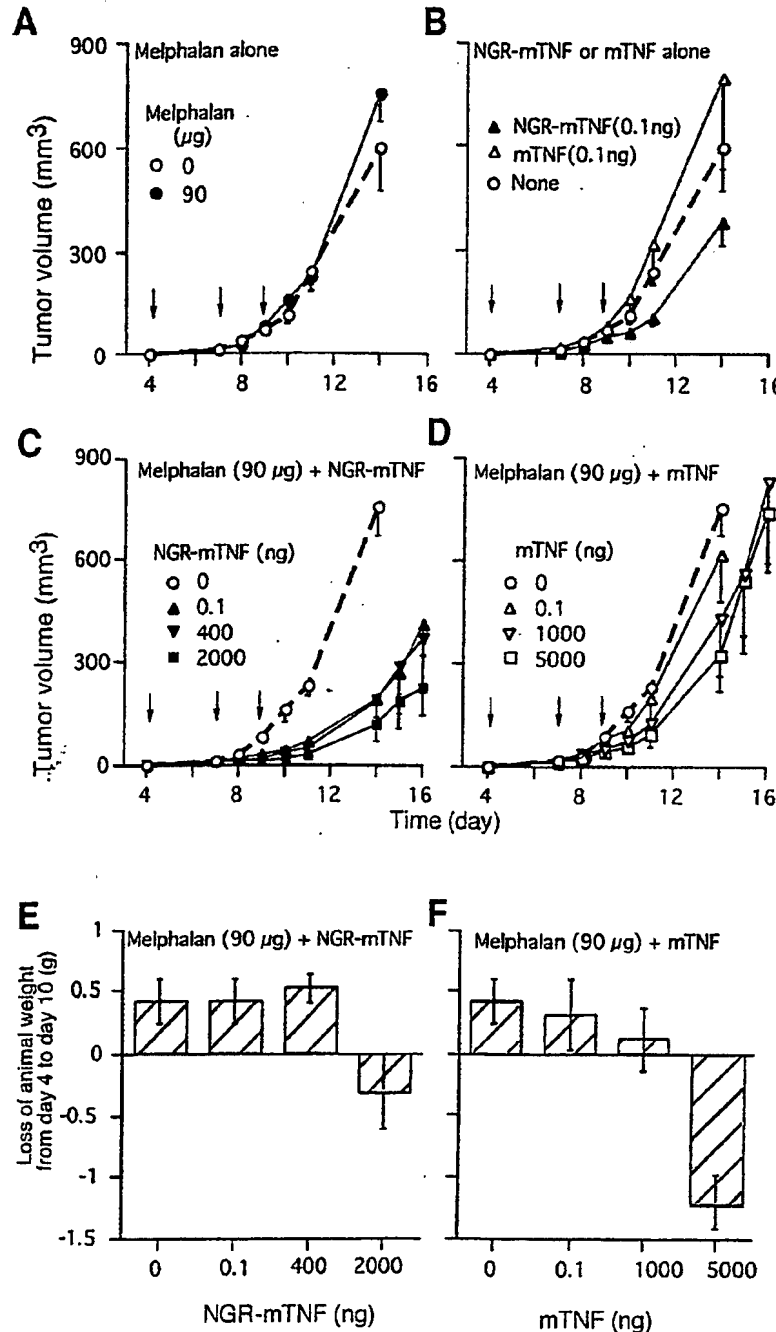
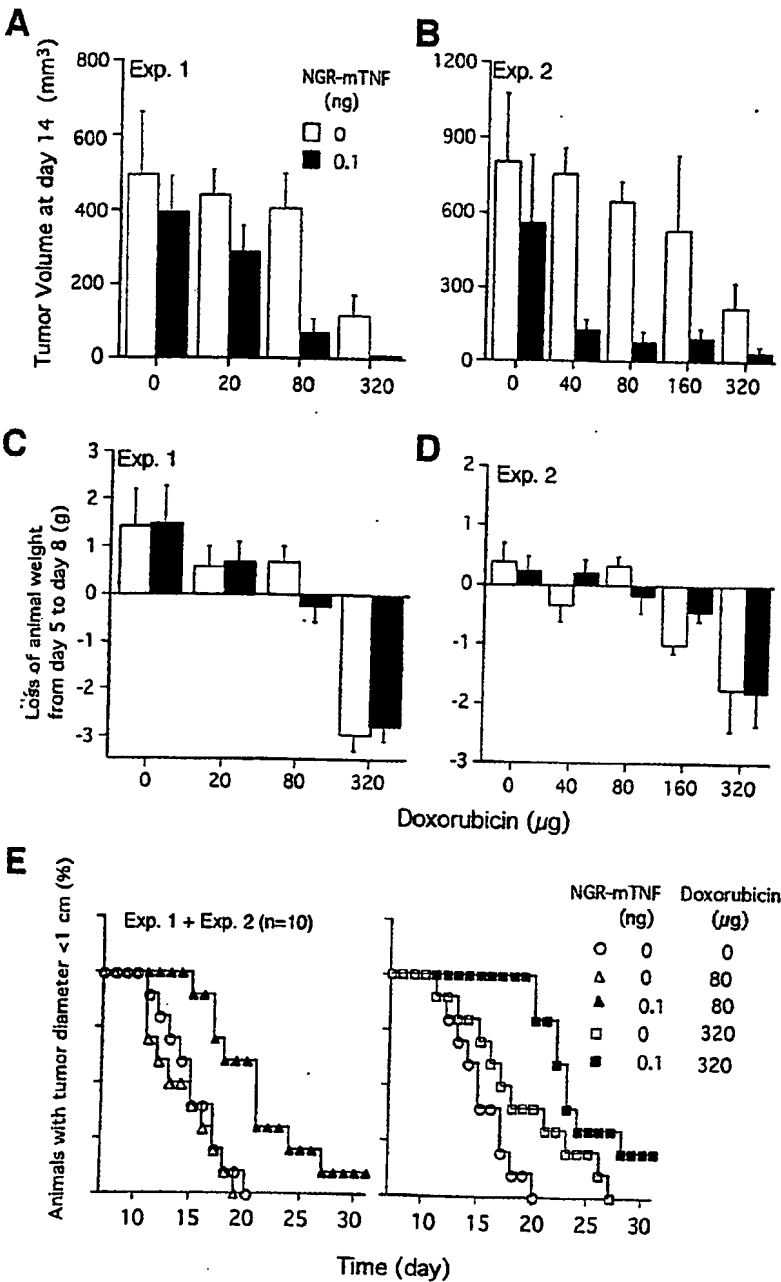
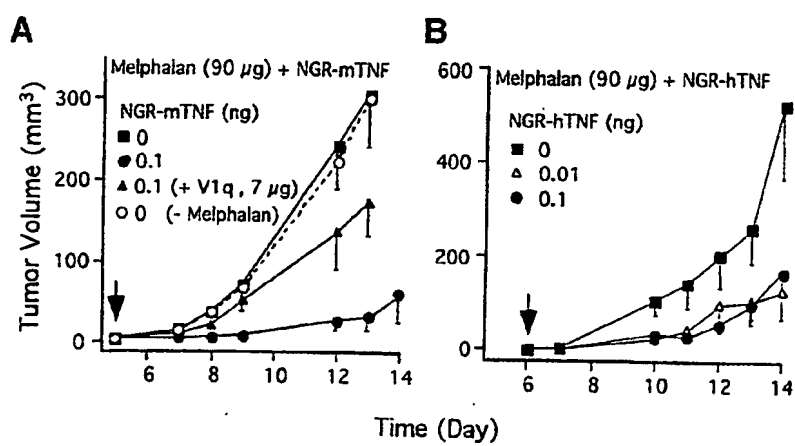


FIGURE 4



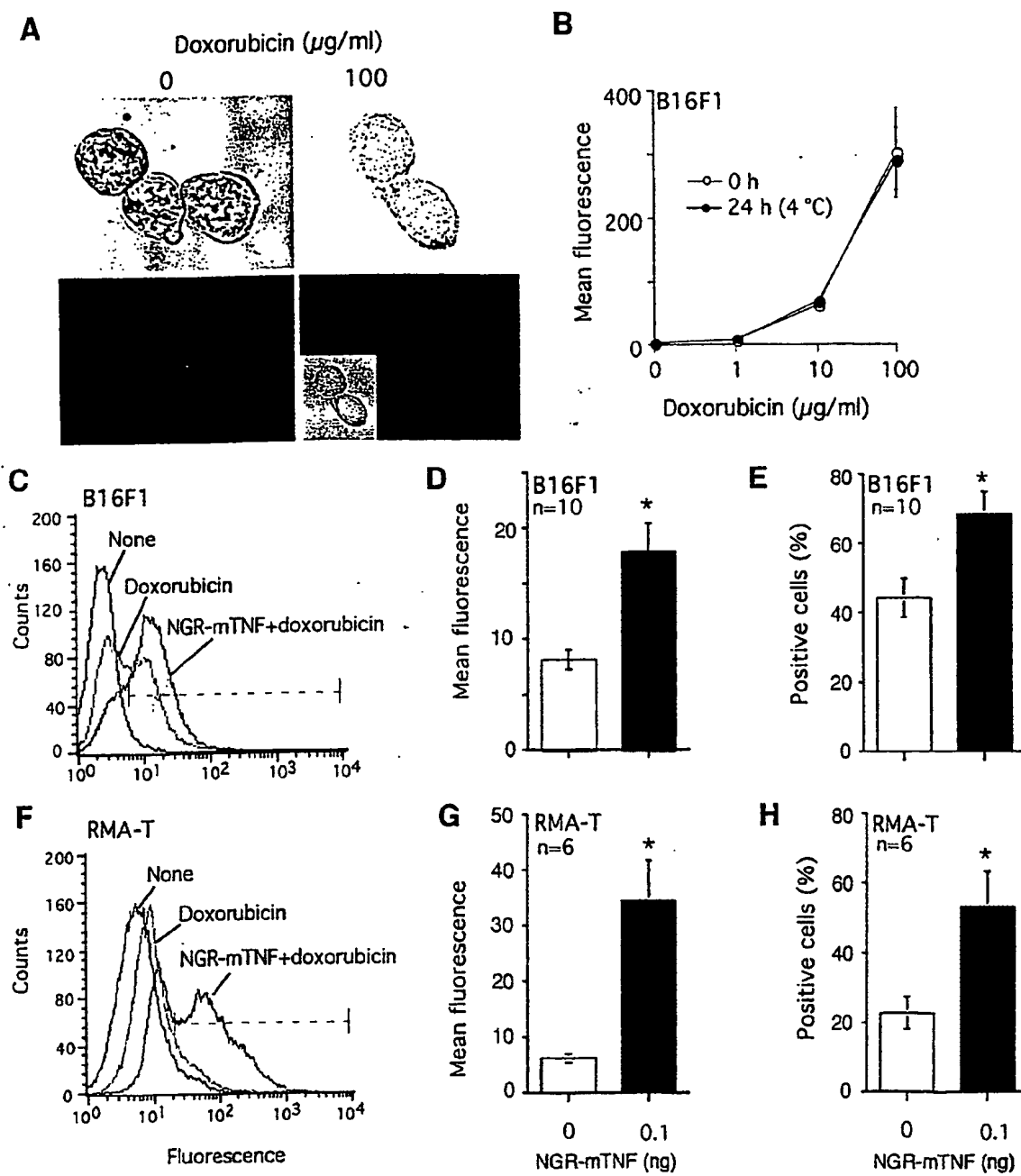
5/10

FIGURE 5



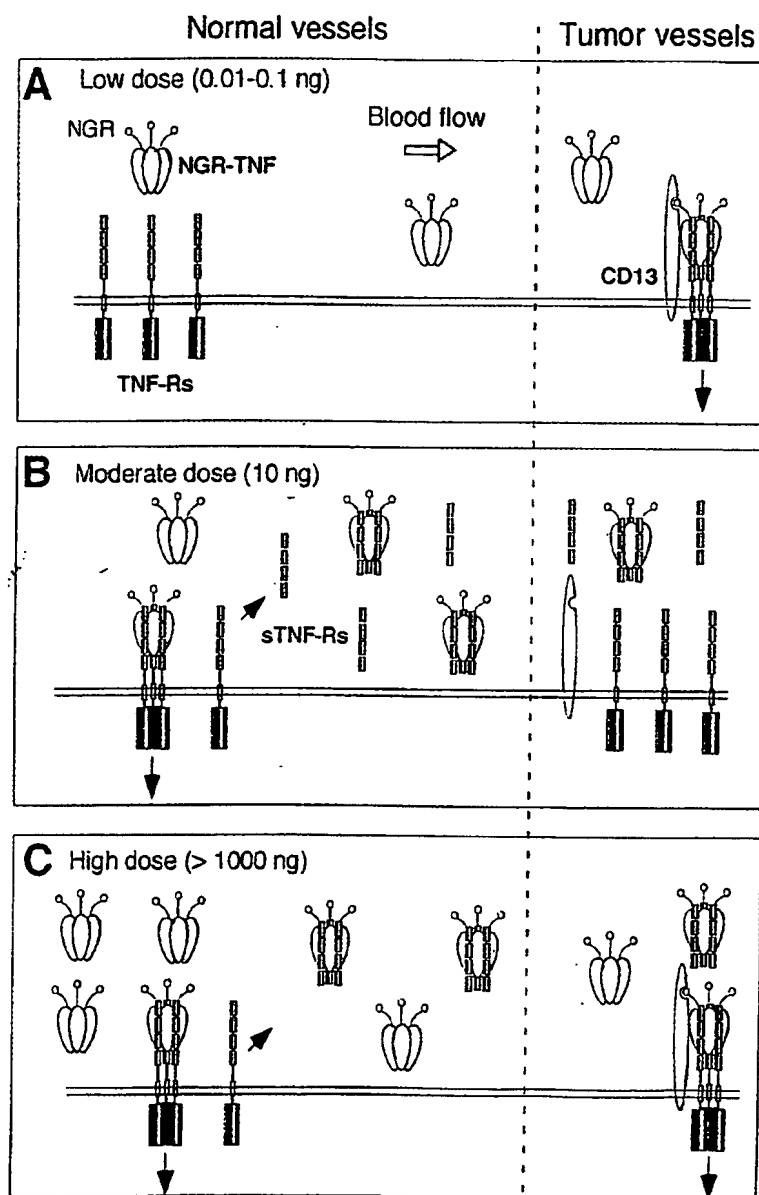
6/10

FIGURE 6



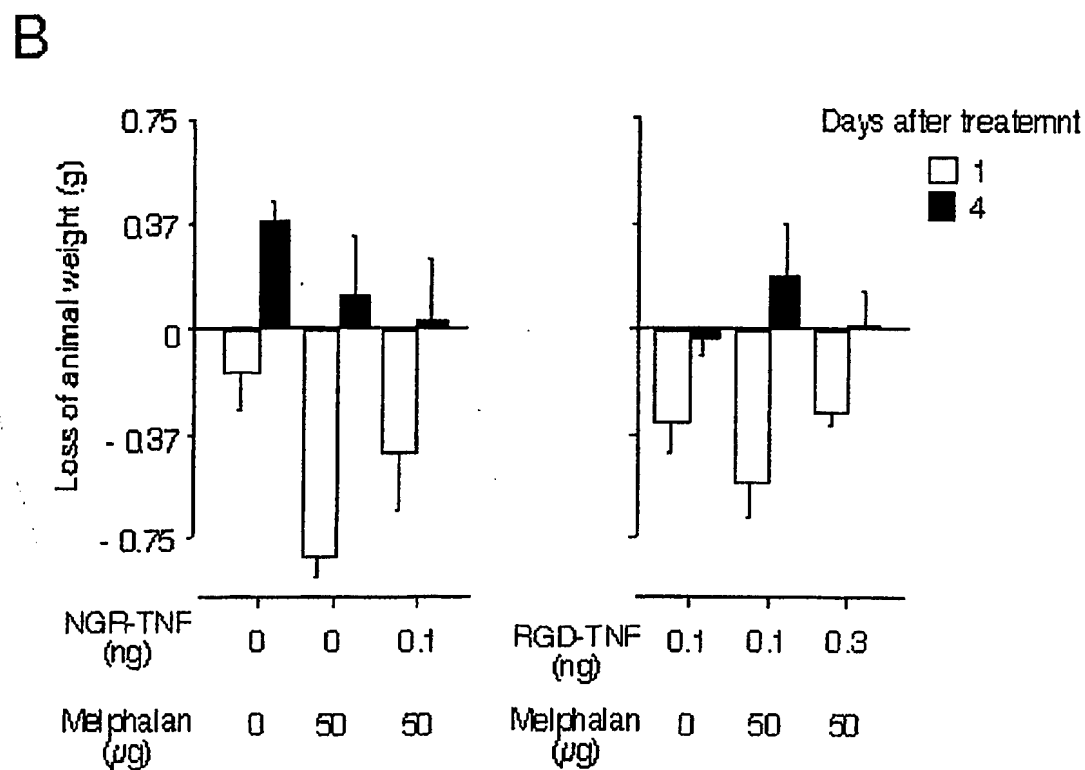
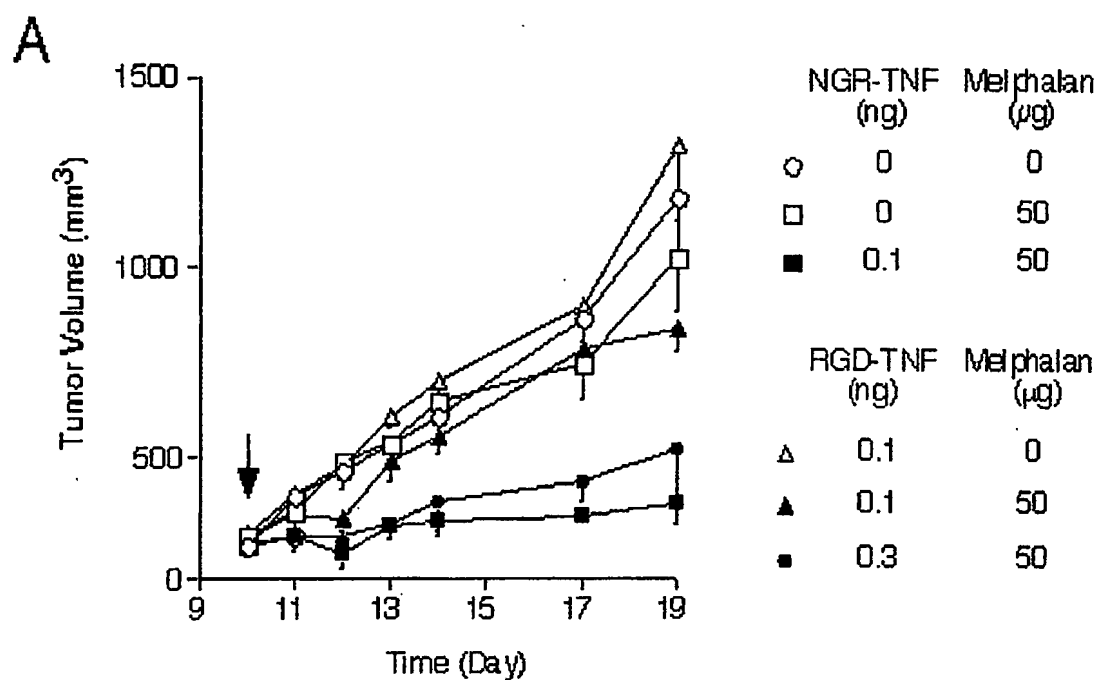
7/10

FIGURE 7



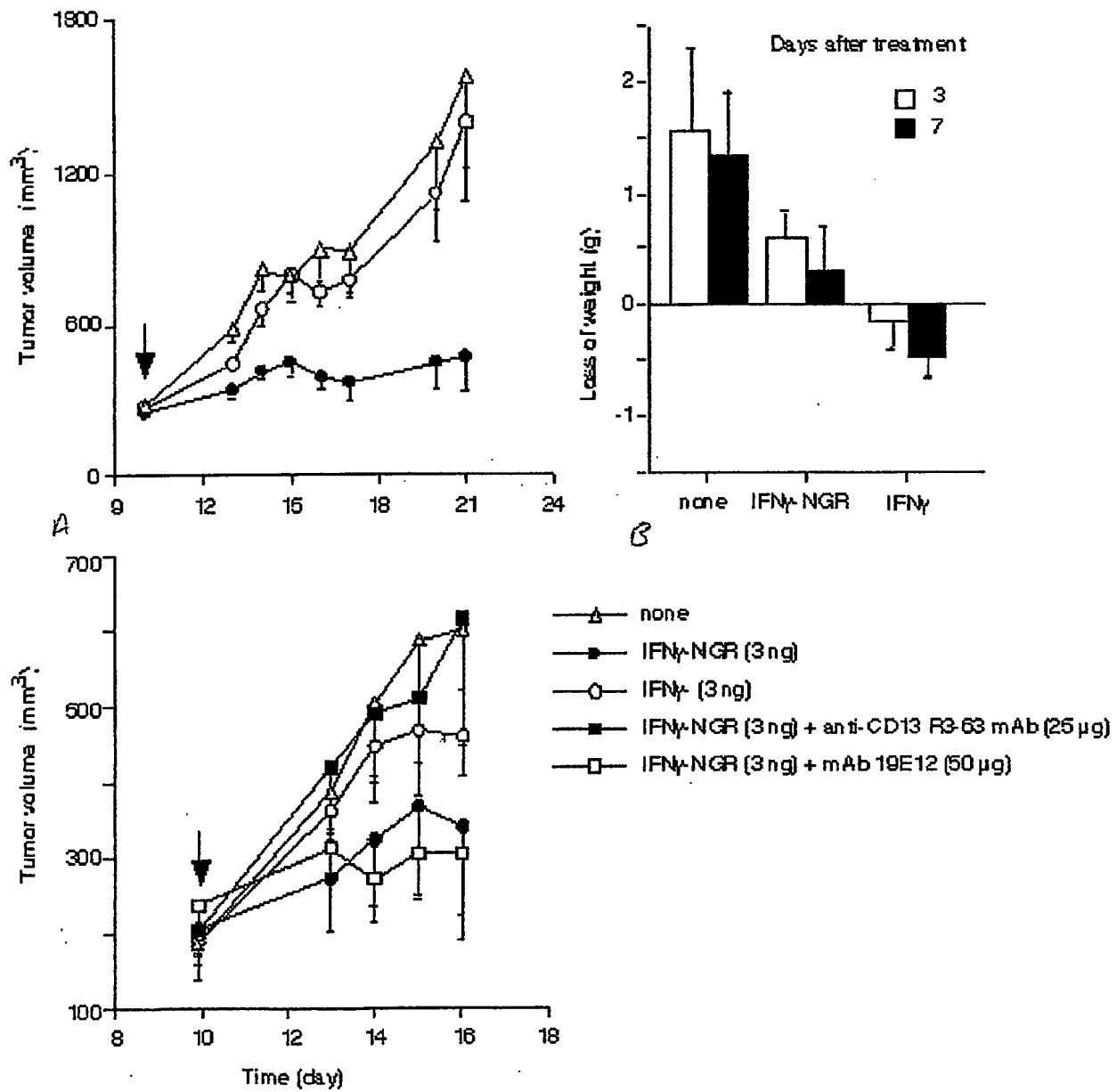
8/10

FIGURE 8



9/10

FIGURE 9



10/10

FIGURE 10

